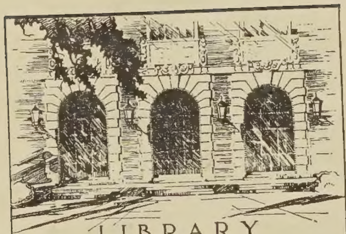

M A N U A L

OF

I N S T R U C T I O N S , F O R M S A N D S C H E D U L E S ,

for use in the

E L E C T R I C A L E N G I N E E R I N G L A B O R A T O R Y

UNIVERSITY OF ILLINOIS.

Prepared by

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UNIVERSITY OF ILLINOIS.

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Department of Electrical Engineering.
University of Illinois.

PLAN OF THE WORK.

This Manual has been prepared to serve as an outline and a guide for the students taking one or more of the following courses in the Electrical Engineering Laboratory of the University of Illinois: E.E. 21, 22, 23, 24, 25, 26. The respective fields covered by these courses will be found outlined on pages, ii - v. The experiments are not arranged in any fixed order for the given courses. Much of the elementary work is taken by all of the students. Selections are made from the more advanced lines of work to meet the requirements of each course assigned to the different classes of students.

The experimental work in the laboratory courses is co-ordinated as far as possible with the lectures and the text-book studies of the other electrical engineering courses of instruction. Actual practice by the student is regularly preceded or supplemented by illustrated lectures and experimental demonstrations bearing upon the subject in hand. The work of the student is not necessarily limited by the schedule, but is extended, as may be directed, while modifications of these experiments will suggest themselves. Every student has an opportunity severals times in each course to have responsible charge of work, as the respective classes are divided into sections, of about six members each, with a different member in charge each day.

Department of Electrical Engineering.
University of Illinois.

COURSES OF INSTRUCTION IN ELECTRICAL ENGINEERING LABORATORY.-Sheet1.

Course 21.- For students in other courses of engineering.

Electrical measurements of direct and alternating currents.

Direct current dynamos and motors:
Study, inspection, operation and performance.

Direct current dynamos: external characteristics and compounding.

Direct current dynamos: coupling in series, parallel and 3-wire system

Alternating current machinery: operation and performance of transformers.- Dynamos, synchronous and induct. motors, synchronous converter

Alternators: parallel working, synchronizing, single and polyphase.

Power measurements and efficiency tests: dynamos, motors, transformers.

Electrical transmission and distribution:
Inspection, management and testing of circuits and systems.

Photometry: elements of photometric measurements of electric lamps.

Course 22.- For junior electrical engineering students.

Direct current dynamos and motors:
Study, inspection, operation and performance.
Mechanical and electrical measurements and data.

Direct current motors: special working, regulation, Ward-Leonard system

Direct current dynamos and motors:
Distribution of potential and magnetization curves
Magnetic determinations, waste flux, leakage coefficients.

Direct current dynamos:
Electrical characteristics; internal external, armature, etc.
Compounding and regulation.
Coupling; in series, parallel and 3-wire systems.
Equalizing compound dynamos.

Stray power and efficiency determinations od dynamos and motors.

Motor-génerator tests, dynamometer measurements, power and efficiency

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University of Illinois.

COURSES OF INSTRUCTION IN ELECTRICAL ENGINEERING LABORATORY.-Sheet2.

Course 23.- For senior electrical engineering students.

Alternating current measurements:
Inductance, capacity and power factor; mutual induction.
Inductance or capacity, in series and in parallel.
Inductance and capacity, in series and in parallel; neutralization.
Power measurements; high potential tests of insulation.

Calibration of direct and alternating current instruments.

Transformers, - study, inspection, operation and performance.

Potential, current and phase transformation: single, polyphase.

Transformer testing: efficiency, losses, regulation, heating, ageing,

Alternating current regulators, auto-transformers, reactance coils.
Study, operation and performance.

Alternators, - study and measurements, mechanical and electrical data.
Inductance of alternator armatures.

Alternators, - inspection, operation and performance.

Alternators, - exploring fields; magnetization and Emf. curves.

Alternators, - electrical characteristics, internal, external, regulation, etc.

Alternators,- parallel working, synchronizing, single and polyphase.

Synchronous motors and synchronous (rotary) converters: operation, performance.

Induction motors; operation, starting characteristics, performance.

Stray power and efficiency determinations: Alt. Cur. machinery.

COURSES OF INSTRUCTION IN ELECTRICAL ENGINEERING LABORATORY. - Sheet 7

Course 24.- For senior students in electrical engineering.

Generators, - regulation, efficiency, capacity, insulation, heating, tests.

Electric Motors, - service performance, regulation and efficiency.

Electric meters and metering, - inspection calibration, installation use.

Electric circuits, - inspection and testing for faults, grounds, insulation.

Electric transmission, - regulation, performance and economics of mixed and composite systems, direct and alternating current.

Electric power plants, - tests of light, power and traction plants.

Course 25.-Advanced course for seniors in electrical engineering

Alternating current measurements:
Effects of the variation of resistance, self-induction and capacity in a series circuit.
Effects of the variation of frequency upon inductance, capacity, lag.
Variation of coefficient self induction with current and the saturation of the iron core.

Alternating current curves, of alternators, synchronous converters and transformers, - comparison of methods and curves.

Armature reactions of alternators and synchronous converters.

Wattmeters, - detailed study of construction, behavior, compensation, and calibration; use in polyphase measurements of power.

Transformers, - grouping, combinations and working in polyphase transmission for best regulation and economy, under given conditions.

Alternators, - synchronizing problems, parallel working, various conditions.

Condensers, - study of, action and place in alternating current sys.

Synchronous converters as condensers, characteristics and performance

Alternating current transmission;
Line regulation by synchronous motors or converters.
Regulation by induction and synchronous motors, same circuits.

Induction motors, - analysis of single and polyphase, with and without condensers, mechanical char. stray power and efficiency.

Special problems in polyphase working and systems.

Department of Electrical Engineering.
University of Illinois.

COURSES OF INSTRUCTION IN ELECTRICAL ENGINEERING LABORATORY. Sheet 4

Course 26.- Photometry for seniors in electrical engineering.

Sensibility of the eye.

Comparison of photometric standards, Candle, Methven screen and Hefner Lamp.

Characteristics of incandescent lamps, constant potential and serie

Variation of luminous intensity about incandescent lamps, effect of filament shape.

Variation of luminous intensity of arc lamps with the inclination open and enclosed A. and D.C.

Mean spherical candle power of [illegible] incandescent and arc lamps.

Use of lenses.

Optical efficiency of an incandescent lamp.

Inspecting Incandescent-Lamps-Vacuum Test and target diagram.

Department of Electrical Engineering.
University of Illinois.

MANUAL OF INSTRUCTIONS, FORMS AND SCHEDULES.

TABLE OF CONTENTS.

TABLE OF CONTENTS.

TABLE OF CONTENTS.

Department of Electrical Engineering.
University of Illinois.

MANUAL OF INSTRUCTIONS, FORMS AND SCHEDULES.

INDEX OF PLATES.

Plates.

Department of Electrical Engineering.
University of Illinois.

INDEX OF PLATES.

Plates.

INDEX OF PLATES.

Plates.

Department of Electrical Engineering. Sheet 1.

University of Illinois.

INSTRUCTIONS for Sections in Electrical Engineering Laboratory. (1)

Memoranda: (1) The Class will be divided into sections of about 6 members, each, arranged alphabetically.

(2) Sections Leaders will follow each other in the same order of rotation.

(3) All othermembers of the section follow each other in same alphabetical order, for assigned duties, as follows:

One Recorder.
Two Switchboard Attendants.
Two Dynamo Tenders.

General Instructions for all Members of Sections:

(1) Obtain copies of all Schedules and Forms, note details of same, and assignments, as posted for given day.

(2) Become familiar with all features of schedule.

(3) Study all references to Laboratory Manuals, etc.

(4) Each member is to hand in report on all the work, done by his section, according to assigned Form.

Instructions for SECTION LEADERS:

(1) Become familiar with the apparatus to be used.

(2) Prepare wiring diagrams of all connections required.

(3) Preliminary run: Ascertain best operating conditions.

(4) Determine upon and assign observation points.

(5) Give signal when observations are to be taken.

(6) Leave everything cleaned up, ready for next Section.

(7) Hand in Section Leader's Report, beforeleaving.

INSTRUCTIONS for Sections in Electrical Engineering Laboratory. (2)

Instructions for RECORDERS: See Instructions for use of Electrical Engineering Laboratory Note Books.

(1) Prepare schedule of headings for tabulation of readings.

(2) Make wiring diagrams of connections, as used.

(3) Keep the log: record readings and note conditions.

(4) Dictate the log to othermembers of section, at the close.

Instructions for SWITCHBOARD ATTENDANTS: See Instructions for the use of Instruments.

(1) Obtain all instruments of proper capacity.

(2) Connect instruments to external circuits, ready for use.

(3) Take all readings, from these instruments.

(4) Operate controlling and power-absorbing devices.

(5) Stand by for any emergencies.

(6) Disconnect, clean and return instruments.

Instructions for DYNAMO TENDERS: See Instructions for Operation,- Schedule O.4; and Arts. A, B, C, of Schedule 4.

(1) Attend to all work about apparatus used.

(2) Get everything ready for operation.

(3) Connect all wiring to and from their apparatus.

(4) Obtain measuring instruments for use at apparatus.

(5) Take all readings of instruments at apparatus.

(6) Secure satisfactory operation during experiment.

(7) Clean up, and leave in satisfactory working order.

University of Illinois.

Section Leader's Report: to be handed in, properly filled out, immediately after completing the work of the day.

No. of Experiment---- Date --

Apparatus used --------

Condition of apparatus when work was completed ---

INSTRUMENTS used (give name and Laboratory Catalogue No.) --

Condition of Instrument when put away---

OUTLINE of work accomplished ----

Combinations, made as per schedule---

Special combinations or work----

DIFFICULTIES encountered---

PRECAUTIONS observed -----

POSSIBLE Sources of Errors ----

E.E. Course No. -- Signed----

Class----- Section---

Department of Electrical Engineering.

University of Illinois.

INSTRUCTIONS FOR CONDUCT OF WORK.

ELECTRIC POWER PLANT TESTS.

Lab. Schedule O.53.

1.- Watches of all observers to be set alike.

2.- All observations to be taken on time, and the time noted. No signals unless ordered.

3.- Note time andcharacter of any special features or changes in the operation of the plant, as throwing on or off new units, circuits, etc.

4.- Members of each section will report for duty at least ten minutes before the hour at which they go on duty.

5.- Ammeter readings, if steady, every five minutes; if unsteady, every minute.

6.- Voltmeter readings, if steady, every five minutes.
if unsteady, every minute.

7.- Water Meter readings, every half hour.

8.- Wattmeter readings, every half hour, if of integrating type.

9.- Take speeds of all machines, engines and dynamos, every half hour.

10.- Steam Pressures, every five minutes.

11.- Note water level in boilers, at beginning, and end with the water at same level, in each boiler.

12.- Each section leader will instruct his successor as to character of observations, loads, changes, etc.

13.- Each section leader, immediately after his tour of duty is ended will make out full report, on regular blanks.

Department of Electrical Engineering.

University of Illinois.

INSTRUCTIONS FOR USE OF NOTE BOOKS. Lab. Schedule 0.54
sheet 1.

Every student will provide himself with two standard Electrical Engineering Laboratory Note Books. Each book has ten sets of sheets like the sample set bound in at end of this manual. These note books will be used each week alternately for report and examination.

Always bring the Manual and Note Book to Laboratory

Perform all work in the order prescribed in assigned schedule.

Note conditions under which each experiment id performed.

Note what is variable and what is kept constant.

Note time and character of any special features or changes.

Readings should be taken at regular intervals, by watch or signal.

Where any sudden change is expected, take more frequent readings.

Fill in Legend, top of first sheet, for each set.

Original Observations.- Log or record on first two sheets.

Laboratory Deductions. Approximate results are to be calculated or plotted, immediately after the performance of each experiment, in order: (a) to detect possible variations in the continuity of the work; (b) to check errors which may require a repetition of the work, in whole or in part. Approximate results and the log or record of original observations form the basis for the final report.

Description of the work. On third sheet. Be brief and to the poi

State the object and purpose of the experiment.

Describe the apparatus employed and explain how it was used.

Describe the methods pursued and state the reasons for such methods.

State precautions observed, difficulties encountered, and how overcom

State the principles illustrated or applied in the experiment.

Give the formulae and illustrate calculations involved.

Interpret the data and the results of given experiment.

Account for phenomena observed by tracing cause and effect, in each.

State final results and draw correct conclusions from.

Department of Electrical Engineering.
University of Illinois.

INSTRUCTIONS FOR USE OF NOTE BOOKS. Lab. Schedule 0.54.
Sheet 2.

Sketches and Diagrams. Draw only on the fourth (unruled) sheet, with neat and firm lines, self-explanatory sketches and diagrams using the conventions and symbols shown on Plate 1. Sample calculations and use of formulae may also be put on this sheet.

Tabulation of Results. Tabulate, in ink, on the fifth sheet, so much of the original observed data as may be necessary to make, with the deductions therefrom, a complete and final table of results of the experiments
Compare results with what is shown by theory or earlier experiments.

Plotting Curves. Use only the last sheet of standard squared paper of each set of report sheets.

Select suitable scales to bring out characteristic features.

Scales should be easily read and interpolated.

(a) Pencil work. Plot points, as observed, in pencil.

To indicate points on different curves use small circles, of different sizes (oO): or other open figures (▫ ◻) but not (x) marks.

Use only standard hard rubber curves in drawing.

Draw a fair curve, by approximate method, where necessary.

Do not try to cover every point, by straight or curved line.

Begin curve at initial or zero point of observation.

End the curve at final observation point not beyond.

(b) Inking in. Use only India ink.

Draw in a fair curve, between circles or other designations of points of observation; do not draw across these points.
Axes and border to be drawn in with firm black lines.
Legend to be placed in lower right hand corner, filled in the same as that at top of first observation sheet: with name and number of experiment, date and name of student; and, a line below, stating what condition or factor was maintained constant; such as speed, in determinations of machine characteristics.

Final Reports, to be completed according to form specified, - A, B, C, etc., and to be handed in for examination, within one week of the performance of the work.

INSTRUCTIONS FOR REDUCTION OF OBSERVATIONS. Lab. Schedule 0.55
Sheet 1.

METHOD OF LEAST SQUARES.

References:-Carpenter, R.C.; Experimental Engineering, pp. 1-15.
Merriman, M.; The Method of Least Squares.
Holman, S.W.; Discussion of Precision of Measurements.
E.W and E., 27: 57 Jan. 11,'96. "Errors in Testing".

"An experimental result whose reliability is unknown is nearly worthless. The grade of accuracy of a measurement must be adapted to the purpose for which the result is desired. The necessary accuracy must be secured with the least possible expenditure of labor,.. and hence with judicious distribution of effort among the various parts of the work". - Holman.

Classification of Errors:

(1) Systematic or constant errors, which affect the same quantities in the same way: (a) instrumental errors, detected by calibration or special methods of adjustment; (b) personal errors, due to the observer's habit and methods and ascertained by comparison of observations.
(2) Accidental errors, whose presence cannot be foreseen nor prevented, but if many observations are made the occurrence of these errors can be predicted by the law of probability, and the probable value of these errors computed by the Method of Least Squares.

Elimination of Errors:

From the results of a series of observations on a presumably constant quantity, all taken under the same conditions, determine the value of the systematic errors and eliminate them. The remaining errors, which cannot be accounted for by imperfections of instruments or peculiar habits of the observer may then be subjected to the method of least squares for determining their probable value.

Axioms relating to the Probability of Errors.

(1) Small errors will be more frequent than large ones.
(2) Errors of excess and deficiency (that is, results greater or less than the true value) are equally probable and will be equally numerous.
(3) Large errors, beyond a certain magnitude do not occur. That is, the probability of a very large error is zero.

Errors of Simple Observations.
(1) The most probable value of a series of observations made on the same quantity is the arithmetical mean.
(2) If the observations were infinite in number the mean value would be the true value.
(3) The residual is the difference between any observation and the mean of all of the observations.

METHOD OF LEAST SQUARES. Lab. Schedule 0.35
Sheet 2.

Let (n) equal the number of observations.
(S) " " sum of the squares of the residuals.

Then: Mean error of a single observation: $\pm\sqrt{\frac{S}{n-1}}$ (1)

Probable error of a single observation: $\pm 0.6745\sqrt{\frac{S}{n-1}}$ (2)

Mean error of the result: $\pm\sqrt{\frac{S}{(n-1)n}}$ (3)

Probable error of the result: $\pm 0.6745\sqrt{\frac{S}{(n-1)n}}$ (4)

Rejection of Doubtful Observations:

(1) If a mistake has occurred and cannot be corrected with certainty, the observations should be rejected.
(2) After making allowances for all constant errors, no results except those which are unquestionably mistakes should be rejected
(3) The remaining discrepancies will then fall under the head of irregular or accidental errors.

Kinds of Measurements:

(1) Direct measurements, made by methods and instruments whose indications give directly the quantity sought.
(2) Indirect measurements, in which the quantity determined is not given directly by measurements taken, but must be calculated from them.
  (a) In this case all of the quantities measured are subject to correction; but it is necessary to correct by abstruse, difficult of lengthened calculations, for influences which make less difference than the least possible unit to be determined by observation.
  (b) The accuracy of the result depends not on the number of decimal places in the result, but on the least errors made in the observations themselves.
  (c) The result is to be carried out to one more place than the errors of observation would indicate as accurate: the last decimal place should make no pretensions to accuracy; the one preceeding should be quite accurate.
  (d) Errors of method may be inherent, results failing to be correct however accurate the components may be, as in stray power method, in which it is assumed that the stray power is the same, empty or loaded, certain conditions being fulfilled

Check Methods:

To obtain most accurate results and get clue to constant errors, independent results should be obtained by as many different methods as possible; and the several results compared.

Mean Errors:

The mean error is the arithmetical mean (average) of the differences between the mean (average) result and the single observations.

If the systematic or constant errors have varied during the experiment, the observations and each partial result should be separately corrected before calculating the mean.

The relative mean error serves as a basis for discussing tests:

$$\text{Relative Mean Error} = \frac{\text{mean error}}{\text{result}}.$$

INSTRUCTION SHEET.- Use of Portable Voltmeters.

L. Schedule O. 61

1.- Handling. Avoid all shocks and jarring actions.

2.- Setting up. Place on firm and level support, at least six feet away from masses of iron, the machine fields or heavy currents.

3.- Connecting. Use flexible cord, as furnished for this purpose. On double scale instruments, connect terminals for higher scale, first, and rake precautionary reading. Plus to plus.

4.- Voltmeter key to be released at once, on reading.

5.- Voltmeter Multipliers always to be connected in series with the instrument. Note, carefully, multiplying factor.

6.- Short Circuits on voltmeters must be absolutely avoided.

7.- Low-reading Voltmeters must not be connected to circuits with voltages beyond the limits of their scale readings.

INSTRUCTION SHEET.- Use of Portable Ammeters.

1.-Handling. Same cafe as in voltmeters.

2.-Setting up. Same care as in voltmeters.

3.-Connecting. Same, as in voltmeters.

4.-Series ammeters may be left in circuit.
Shunt ammeters, must be connected up only for reading.

5.-Ammeter shunts to be in series with the circuit, and ammeter in shunt with the same, by connections provided for the purpose.

6.-Machines must not be short circuited through an ammeter.

7.-Use ammeters on circuits only within scale readings.

NOTE:-1.- Obtain and return instruments through Storekeeper.
2.- Avoid wiping glass over instrument before reading.
3.- Read all mirror instruments, normally.
4.- Never remove instrument covers. Report faults and return.
5.- Return instrument clean and in good condition.

Department of Electrical Engineering.

University of Illinois.

INSTRUCTION SHEET.- Use of Indicating Wattmeters. Lab. Sheet 0.62.

1.- Readings of indicating wattmeters are in true watts or kilowatts, regardless of power factor of circuit.

2.- Handling.- Avoid all shocks and jarring actions.

3.- Setting up.- Place on a firm and level support at least six feet away from machine fields or heavy currents.

4.- Connecting.- See Sheet of "Diagrams of Connections for Laboratory Instruments". Connect current coils with special connectors furnished with instrument. Connect pressure coil with flexible cord.

5.- Current coils are to be connected in series in one side of the circuit.

6.- Presure coils are connected across circuit.

7.- On double scale instruments, connect pressure terminals to higher scale first, and take precautionary reading.

8.- Release key at once after taking every reading.

9.- Multipliers are to be connected in series with presure coil and in position shown on Diagram, NEGLECT OF THIS WILL BURN OUT INSTRUMENT Note, carefully, multiplying factor.

10.- Use instruments only in circuits within scale readings.

11.- Injury from large initial currents must be guarded against, as when starting induction motors under load, by temporarily short circuiting the terminals of the current coils till normal or steady conditions are assured.

Department of Electrical Engineering.

University of Illinois.

INSTRUCTION SHEET.- Use of Integrating Wattmeters. Lab. Sheet 0.63.

1.- Readings of integrating wattmeters are in true watthours or kilo-watt hours regardless of power factor.

2.- Handling. Avoid all shocks and jarring actions.

3.- Setting up.- Suspend or place in a perfectly level position, away from [illegible]active fields or heavy currents.

4.- Connecting.- See Sheet of "Diargrams of Connections of Laboratory Instruments". Connect main terminals in series in one side of cir-cuit. Connect potential terminal across to other side of circuit.

5.- If no constant is given the instrument reads directly in watt-hours. If constant is given, multiply by it to reduce to watt-hours.

6.- If case is opened be very careful that no dirt gets on commutator or rotary disk.

7.- When properly connected meter disk will always rotate in direction indicated by arrow on disk or other revolving part.

8.- Use instruments only in circuits within specified limits as noted on name plate.

INSTRUCTIONS FOR USE OF CRADLE DYNAMOMETER. Lab.Schedule 0.71
Sheet 1.

References:-
Flather, J.J.- Dynamometers and the Measurement of Power; pp.98-103.
Nichols, E.L.- Laboratory Manual Vol.II., pp. 32-34.
Holman, S. W.- Discussion of the Precision of Measurements; pp.130-38

General Observations and arrangements:

The power delivered or absorbed by any machine (motor or dynamo) is measured by supporting it on a swinging platform, suspended from knife edges, and thence determining the torque or turning moment by weighing on a scale beam, the tendency of the ~~machine~~ driving belt to rotate the machine, or the tendency of the machine to rotate through the magnetic reactions between the armature and field.

General Conditions to be Fulfilled:

(1) The horizontal knife edges must be exactly in line.
(2) The axis of rotation of the armature must be in line with the axis of oscillation of the cradle; that is, in the line which passes through the knife edges.
(3) The centre of gravity of the system, including the machine, cradle and all attachments, must be very slightly below the axis of oscillation, that the system may have the necessary degree of sensitiveness, like a balance.

Precautions to be observed.

(1) All fastenings used in mounting the machine on the cradle, and all attachments, must be firm and secure.
(2) Belt should preferably be run vertically, unless provision is made to counteract its side pull, if run otherwise.

Preliminary adjustments; machine at rest.

(1) Adjust with utmost care, axis of machine to line of knife edges.
(2) Adjust the center of gravity, for the desired sensitiveness, by raising or lowering the auxiliary weights, on vertical standards. When properly adjusted, the system should slowly and sensitively oscillate like a balance; a weight of 1/2 lb. at end of scale beam, moving the index pointer on the index scale through one division, would indicate that the index error of this scale would be neglible.
(3) Balance the dynamometer and the machine, at rest, with belt off, and the weights at zero.

Operating adjustments:

(1) Operate the machine as a motor, without belt, to determine if the dynamometer remains balanced; if not, seek for cause and remedy this defect.
(2) Adjust belt to pull as lightly as possible.

INSTRUCTIONS FOR USE OF CRADLE DYNAMOMETER. Lab. Schedule 0.71
Sheet 2.

Note: "When all these (adjustments) are attended to it is doubtful whether measurements of power accurate to one per cent can be obtained". - Holman.

Operation:-

(1) All loads on the machine must be applied very gradually.
(2) Adjust sliding weights till balance is obtained.
(3) Balance is indicated by scale arm in horizontal position and the index pointer at zero.

Observations while running:

(1) Note time or number of the observation.
(2) Revolutions per minute, by tachometer.
(3) Load, by position of weights on arm.

Note: In motor testing, friction of bearings, hysteresis, or foucault currents, cannot affect the dynamometer reading. Energy consumed in overcoming these losses in the machine enters as electrical energy and does not tend to tip the system.

In dynamo testing, mechanical energy required to overcome these losses is supplied by the driving belt and measured by the dynamometer in the usual way.

Calibration of Cradle Dynamometer.

The laboratory cradle dynamometer has scale beam graduated to read watts per 1,000 revolutions.
Hence, if preceeding instructions have been complied with:

$$\text{Watts} = \frac{\text{Rpm.}}{1000} \times (\text{Scale reading}).$$

$$= \frac{\text{Rpm.}}{1000} \times \left(\frac{2\pi \times 1000 \times L \times W \times 746}{12 \times 33{,}000}\right)$$

Where (L) is inches that the weight (W) is moved on arm to produce equilibrium when the machine is running.

Questions and Demonstrations:
(1) Show how the above equations are derived?
(2) Use them to determine if the given dynamometer is properly graduated, for the weights used; or, if weights are correct for the graduations of the scale?
(3) What is the capacity of the given dynamometer?
(4) Find weight at end of arm equivalent to one large division?
(5) Explain why the zeros are placed where they are?
(6) Explain and illustrate action when torque is reversed.
(7) When motor or dynamometer runs with its belt off, why does the dynamometer tip while speed is changing, although balanced for constant speed?
(8) Illustrate all possible characteristics by using a Rotary.

Department of Electrical Engineering.

University of Illinois. Form A.

Requirements of Laboratory Work and Report.

Write a Report on the assigned work, as performed under the several items of the given Schedule, referring to the same, by the designated numbers or letters, and treat in the following order:

1. Object of the work, in brief.

2. Methods of conducting the work, and reasons for the same.

3. Sketch diagrams of electric circuits and of connections used.

FORM B.

Write a Report on the assigned work, as performed under the several items of the given Schedule, referring to the same, by the designated numbers or letters, and treat in the following order:

1. Object of the work, in brief.

2. Methods of conducting the work and reasons for the same.

3. Sketch diagrams of electrical circuits and connections used.

4. State precautions observed in conducting the work:

   (a) In connecting the several circuits.

   (b) In handling and in using the instruments.

   (c) In connecting the instruments for observations.

   (d) In use of the electrical energy.

   (e) In operating or other work with machine or appliance.

   (f) In taking observations and making measurements.

5. Explain the possible sources of error:

   (a) In the electrical circuits and connections.

   (b) In the use of the electric energy.

   (c) In the use of the instruments.

6. State the conclusions to be drawn from the observations and from the results obtained.

Department of Electrical Engineering.
University of Illinois. FORM C.

Requirements of Laboratory Work and Report on the Operation of Electrical Machinery and Appliances.

Write a Report on the Operation of the assigned dynamo, motor, transformer or other electrical machinery or appliance as performed under each specified item of the given Schedule of Operation, referring to the same by the designated numbers or letters; and treat in the following order:-

(1) Sketch diagrams of connections used for each set of operations.

(2) Explain the behavior and the characteristic features of the operation and performance of machine or appliance, when examined under the conditions prescribed for each item.

(3) Describe how the regulation and control was accomplished.

(4) Number and tabulate the observed readings, per given schedule, illustrating the characteristic features of operation.

(5) State conclusions to be drawn from these observations, referring to the instrumental readings taken for the various sets.

(6) Plot curves, as specified , showing the relations between any two assigned variables; and note on same sheet what operating conditions were maintained constant.

(7) Make a study of and report on the Belt Problem, as follows:-

(a) Lining up of belt and parallelism of shafts.

(b) The per cent. slip of the belt, at different speeds.

(c) The lineal speed of belt, in feet per minute.

(d) Horse power transmitted to machine, full load.

(e) Capacity of driving belt; allowable and actual.

(f) The working, effective, or driving tension: $(T_1 - T_2)$.

SUMMARY or Electrical Data. Analysis of Dynamos and Motors.

No.	Items.	Sym.	Formulae.	Machines.
1	Type of Machine.			
2	No. of Poles.			
3	Capacity: K.W., or H.P.			
4	Speed, Rpm.,			
5	Volts, normal excitation,			
6	Current, normal load,			
	ARMATURE:			
7	Resistance, cold, F.			
8	" hot, F			
9	Current, normal Emf. no load			
10	" Fl. Ld. Ext. Cr.			
11	" total,			
12	Volts, normal, no load			
13	" Fl. ld., Ext. Cir.			
14	" lost in Armature			
15	" total, full load.			
16	Starting Box Resist. total, cold,			
17	Temp. Cyl. Surf. no load.			
18	" " " full load			
19	" End surface, no load			
20	" " " fl. Ld.			
21	" Commutator, no load			
22	" " Fl. Ld.			
	Temp. of Arm. conductors, Calc. from Res. Meas.:			
23	" at no load,			
24	" at full load,			
	SHUNT Fields:			
25	Resistance, cold F.			
26	" hot, F.			
27	Temp., by Therm., no Ld.			
28	" " " Fl. Ld.			
	Temp. Calc. from Res. Measurements:			
29	" no load			
30	" Fl. "			

No.	Items.	Sym.	Formulae.	Machines.
31	Res. of Rheostat, total, cold			
32	Current, normal Emf., no Ld.			
33	" " Fl. "			
34	Sketch of Field Spool.			
35	Net dimensions of the winding space: - - - - - -			
36	Radiating surface, one spool, net winding space. -			
	SERIES Coils:			
37	Resistance, cold, F. - - -			
38	" hot, F - - - -			
39	Res. Series shunt, Sect. 1 -			
	" " " " 2 -			
	" " " " 3 -			
40	Current, full load, - - -			
41	Kind of Compounding- - - -			
	COMMUTATOR:			
42	No. Seg. brush lead, 1/4 Ld.			
43	" " " " 1/2 Ld.			
44	" " " " 3/4 Ld.			
45	" " " " Fl. Ld.			
46	" " " %" Over Ld.			
47	Material of brushes of Com.			
48	Area of brush contact, sq. in.			
49	Amp. per sq. in. of Pos. brush contact, full load.			
	WATTS lost, in Armature:			
50	Copper losses, full load,			
51	Stray Pow. Loss,-Hysteresis,			
52	Core losses.			
53	Total watts lost in arm.			
54	" in % of output, actual:			
55	" " % " " allow=			
	WATTS lost in Fields:			
56	Shunt field, full load: - -			
57	" in % of output, actual.			

SUMMARY or Electrical Data. Analysis of Dynamos and Motors.

No.	Item.	Sym.	Form.	Machines.
58	Shunt in % output, allow - -			
59	Series field, full load: - -			
60	" in % of output, actual:			
61	" " % " " allow:			
62	Total Watts lost, - - - - - (Note: If series coil overlaps shunt, or vice versa, use total watts, for field losses.)			
	RADIATING SURFACES:			
63	Kind: cylindrical, sq. in. - --			
64	end surfaces sq. in.- -			
65	total Rad. Surface - - -			
66	Watts per Sq. in. Rad. Surf.: -			
67	in armature, actual - -			
68	" " allow:			
69	" shunt, actual, - -			
70	allow: - - -			
71	in series, actual, - - -			
72	allow: - - -			
	RATIOS of Resistances:			
73	Shunt to Armature: - - - - -			
74	Shunt to Rheostat (total) - -			
75	Shunt to series: - - - - - -			
76	Arm. to Start. Box: (total) -			
77	Arm. to Series (long Shunt)			
78	Series to its Shunt: - - - -			

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University of Illinois. Form E.

Requirements of Laboratory Work and Report in Determination of the Distribution of Potential.

Write report of work according to prescribed Form.

Plot following Curves, on Standard Squared Paper:-

A. - Distribution of Potential by Mordey's Method:-

1. Rectangular diagram, no load.
2. Rectangular diagram, full load.
3. Polar diagram, no load.
4. Polar diagram, full load.

B. - Distribution of Potential by Thompson's Method:-

1. Rectangular diagram, no load.
2. Rectangular diagram, full load.
3. Polar diagram, no load.
4. Polar diagram, full load.

C. - Integrated Curves of Distribution of Potential, from the Daba given by Thompson's Method:

1. Rectangular diagram.
2. Polar diagram.

Department of Electrical Engineering.
University of Illinois. FORM C, sheet1.

Requirements of Laboratory Work and Report in Subject of Stray Power and Efficiency.

Write report of work, according to prescribed form:-

Plot designated curves, of the following list, on Standard squared paper: on base line of watts, or of per cent full load (proportional part of full rated load) - of output, if dynamo, and of input, if motor is being tested:-

1. Loss curves, showing individual (separated) losses, and the aggregate (total) loss, in watts, at various loads.

11. Power or Load Curves, showing:-

(a) total true watts; (b) total apparent watts.

111. Idle Watts Curve, for alternating current work.

1V. Power Factor Curves, for alternating current work:-

(a) Without Condenser: (b) with Condenser, in circuit.

V. Efficiency Curves:-

(a) Electrical Efficiency: (b) True Commercial Efficiency.

(c) Apparent Commercial Efficiency.

(V1). Volts drop at the machine.

V11. Starting Current Curves.

V111. Speed Characteristics:

(a) Shunt motor; (b) Series motor.

1X. For Induction motor, plot curve of per cent slip in speed.

X. Acceleration characteristic.

X1. Retardation characteristic.

X11. Torque curve for motors.

Requirements of Laboratory Work and Calculations in Determination of

Stray Power and Efficiency.

1. - Stray Power Losses, equal sum of watts lost in armature necessary to overcome mechanical friction, and hysteresis and eddy current losses.

2. - Total Losses, equal sum of watts lost in stray power and watts lost in heating armature conductors and watts lost in field windings.

3. - Gross Output, equals sum of watts available in external circuit and watts lost in heating armature conductors and watts lost in fields: equals Gross Input less the Stray Power Losses.

4. - Gross Input, equals Gross Input and Stray Power Losses: equals Total Loss (watts) and watts available in the external circuit.

5. - Gross Efficiency, equals Efficiency of Conversion, equals Gross Output divided by Gross Input.

6. - Electrical Efficiency (Economic Coefficient), equals Available Output in external circuit divided by (Gross Input less the Stray Power Loss.)

7. - Commercial or Net Efficiency, equals Available Output in external circuit divided by Gross Input.

NOTE:- Make use of data on Form D. and insert losses on same.

Department of Electrical Engineering.

University of Illinois. FORM H.

Requirements of Laboratory Work and Report.

Write a report on the assigned work, as performed under the several items of the given Schedule, referring to the same by the designated numbers or letters, and treat in the following oredr order:

1. Tabulate the observed readings in the order specified.
2. Reduce the observations, whereever required, giving formulae used and illustrate calculations involved.
3. Apply Method of Least Squares, to specified sets of observations of single variables.
4. State the conclusions to be drawn from the observations and from the results obtained.
5. Plot curves, as specified, showing the relations between any two assigned variables; and note on same sheet what operating conditions were maintained constant.

DEPARTMENT OF ELECTRICAL ENGINEERING.

University of Illinois.

Data Form.

No.	Items.	Machines.
1.	Manufacturer - - - - - - - - - -	
2.	Manufacturer's number - - - - - - -	
3.	Type of Machine - - - - - -	
4.	No. of Poles - - - - - - - - - -	
5.	Capacity: K.W. (Dyn.); H.P. (Mot.)	
6	Speed, Rpm., - - - - - - - - -	
7	Frequency, cycles per second -	
8.	Volts, normal excitation - - -	
9.	Current, normal load - - - - -	
	Mechanical Data.	
10.	Shaft: material - - - - - - - -	
11.	" Dia,. core portion - -	
12.	" " collector portion	
13.	" " journal bearing -	
14	" " pulley fit - - - -	
15.	Bearings: kind - - - - - - - -	
16	" length of, - - - - -	
17	Pulley: Diam. over crown - - -	
18	" face width, - - - - - -	
19.	" size keyway - - - - - -	
20.	Belt: material, - - - - - - - -	
21.	" thickness, single or double	
22.	" " in inches, - -	
23.	" width of, - - - - - - - -	
24.	" lineal speed, ft. per min.	
25.	" per cent slip, normal - -	
26.	" capacity, allowable - - -	
27.	" " actual, - - - -	
28.	" working tension, full Ld.	
	ARMATURE.	
29.	Windings; type of, - - - - - - ring, shuttle, form, bar,	
30.	" coil, lap, wave, chord, -	
31.	Coils, open or closed - - - - -	
32.	" method of connection - -	
33.	" number of, - - - - ; - -	
34.	" length of, over all, - -	
35.	" width of, - - - - - - -	

19.

DEPARTMENT OF ELECTRICAL ENGINEERING.

University of Illinois.

Data Form. Sheet 2.

No.	Items.	Machines.
36.	Coils, aperture of, - - - - -	
37.	" " width - -	
38.	" No. per pole - - - - -	
39.	" turns per coil - - - -	
40.	" not of wire - - - - - - -	
41.	Conductors: bare, diameter - -	
42.	" " width, depth	
43.	" area cross-section	
44.	" length of active -	
45.	Insulation of conductors, kind	
46.	" thickness of, - - -	
	Smooth Core Armature.	
47.	Diam. over all - - - - - - - -	
48.	" of core, external, - - -	
49.	" " " internal - - -	
50.	Length over all - - - - - - -	
51.	" of core, effective- - -	
52.	Laminae, thickness of, - - - -	
53.	" insulation betw. (total)	
54	Ventilating ducts, No. of - -	
55.	" width of each,- - -	
	Toothed Armature.	
56.	Diam. over teeth - - - - - - -	
57.	" at bottom of slots - - -	
58.	" of core, internal - - -	
59.	Length, over all - - - - - - -	
60.	" of core, effective - -	
61.	Laminae, thickness of, - - -	
62.	" insulation betw. (total)	
63.	Detail dimensioned sketch of stamping of tooth and slot - -	
64.	Sketch arrangement of conductors in slots,	
65.	No. of teeth - - - - -- - - -	
66.	Ventilating ducts, No. of, - -	
67.	" width of each, -	
	Commutator.	
68.	Diam., external - - - - - - -	
69.	" internal - - - - - - - -	

20-21

DEPARTMENT OF ELECTRICAL ENGINEERING.
University of Illinois.

Data Form. Sheet 3.

No. Items. Machines.

70. Length, over all - - - - - - - -
71. " active - - - - - - - - -
72. Insulation, thickness betw. seg.
73. Segments, No. of - - - - - - -
74. " No. of per slot - -
75. Insulation, width of, at face,
76. COLLECTOR - Slip Rings at root,
77. Number of, - - - - - - - - - - -
78. Diam., external, - - - - - - - -
79. " inetrnal - - - - - - - -
80. Width of, - - - - - - - - - - -
81. Thickness of - - - - - - - - - -
82. Distance, centre to centre - - -

BRUSHES.

83. Type of brush,-tangent, radial -
84. Material of brushes - - - - - -
85. Number of sets of brushes - - -
86. No. of brushes, one set - - - - -
87. Length, of each brush - - - - -
88. Width, of each brush - - - - - -
89. Thickness of each brush - - - -
90. Area of contact, one brush - - -
91. " " " set brushes

FIELD WINDINGS.

92. Type: shunt, series, compound, -
93. Sketch field coil or spool, showing section, par ing section, parallel to its axis.
94. Net winding area - - - - - - - -
95. Insulation, thickness flanges, -
96. " " of bobbin Ins
97. Turns, per spool, shunt - - - -
98. " " series - - - -
99. Wt. of wire, on fields, per spool
" " of shunt
100. " " " series
101. Field conductors, bare diam., -
102. " " width × depth

22-23

No.	Items.
102.	Field conductors bare, diam. series
103.	" " width × depth, series -
105.	Radiating surfaces: cylindrical, sq. in.
106.	" " ends, sq. in.,
107.	" " total, sq. in. - per spool,
	FIELD FRAME- Poles.
108.	Sketch pole: faces, horns, profile with dimensions, - - - - - - - - --
109.	Pitch, mean dis. betwn. pole centres
110.	Pole arc: angle subtended - - --
111.	" " circumferential length -
112	" " axial length - - - - --
113.	Ratio of pole arc divided by pitch
114.	Diam. of polar bore - - - - --
115.	Depth of air gap, single - - --
116.	Dist. betwm. adjacent tips, - --
117.	Mean length Mag. Circ. of pole- --
	MAGNET CORE.
118.	Sketch and dimension, cross section:
119.	Net area magnet core, - - - - -
120.	Length of core, betw. coil flanges, or, length of magnetic circuit of the core, - - - - - - - - - -
	YOKE
121.	Sketch cross-section, and dimension,
122.	Dist. betw. centre lines of cores-
123.	Mean length of Mag. Circ. of Yoke -

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University of Illinois. Form N.

ELECTRIC POWER PLANTS. Requirements of Report.

Write a Report containing a brief description and record of performance of the Plant.

(1) Object of the Test, to obtain plant economy and ratings.

(2) Description of the plant, from boilers to switchboard.

(3) Performance of the plant; explain the behavior and characteristics features of the operation of the plant in general and note any special items of importance.

(a) Behavior of individual units, boilers, engines, generators, etc.

(b) Behavior of plant in the aggregate.

(c) Any special features of regulation or control.

(d) Note what operating conditions were maintained constant.

(4) Method of conducting the test:-

(a) Assignments for continuous work during test.

(b) Observations and readings: when and where taken.

(c) Precautions observed: in conduct of test and in taking observations.

(5) Plot graphical log of test, on time base,

(6) Obtain averages from arithmetical means or by integrating with planimeter the plotted curves of the graphical log.

(7) Tabulate data and results of observations, per Form P.

(8) Obtain plant ratings: K.W. hours per 1,000 lbs. feedwater, or per 1,000,000 B.T.U. supplied to the system.

(9) State conclusions to be drawn from the performance of the plant and from the observations and results.

Department of Electrical Engineering.
University of Illinois.

ELECTRIC POWER PLANTS. DATA Schedule.

Form P. Sheet I.

General:-

1 Name of Plant ---------------

2 Location ------------------------

3 Date of Test -------------------

4 Time of Test -------------------

5 Object of test -----------------

6 Character of Load ---------------

Steam Boilers:-

7. Maker -------------------------

8. Number of boilers ---------------

9 Type ---------------------------

10 Rated Capacity of boiler plant ---

11 Pressure, normal, gauge ----------
avarage during test -----

12 Coal used, kind, ----------------

13 Feed water Temp., average. -------

Water Meter:-

14 Maker --------------------------

15 Maker's Number -----------------

16 Type ---------------------------

17 Where located -------------------

18 Scale Readings,(limits),cu.ft.---

19 time interval,hrs.

20 Temp. service water, average. ----

Steam Engines.

21 Maker --------------------------

22 Number of Engines ---------------

26

Form P. sheet2.

ELECTRIC POWER PLANTS. Data Schedule.

23 Type ---------------------------------

24 Rated capacity of Installation ---

25 Average Ind. H.P. during test.----

26 Speed, normal, Rpm., -------------

27 average, during test, -----

28 Cylinder: diameter x stroke ------

29 Fly Wheel, diameter -------------

30 rim section, ----------

31 weight, (approximated).

32 Method of Driving -----------------

33 Belt Pulley: diameter, feet ------

34 " " face width, ins, ----

35 Driving Generators, -------------
(Designated by Numbers).

GENERATORS.

36 Maker ----------------------------

37 Maker's Number -------------------

38 Number in use --------------------

39 Type -----------------------------

40 No. of Poles ---------------------

41 Capacity, K.W. -------------------

42 average during test -----

43 per cent, full load. ----

44 Speed, normal, Rpm., ------------

45 " average during test, ------

46 Frequency -----------------------

47 Voltage, normal -----------------

ELECTRIC POWER PLANTS. Data. Form P. Sheet 3.

Items.

48 Current, normal
48 Voltage average, during test ------

49 Current, normal ------------------

50 " average, during test. ---

51 How driven, (belted or direct con)-

52 Belt Pulley: diameter, ins., ------

53 " " face width, ins., ---

54 Belt: width x thickness, ins.

ELECTRIC SUPPLY:

55 Incandescent Lamps, normal, No.---

56 Arc Lamps, normal No -------------

57 Motor service, K.W. -------------

58 Street Cars, normal, No. ---------

RESULTS OF TEST:

59 Volts, Generator Panel, mean -----

60 Amperes, " " mean -----

61 K.W. per hour, Volt-Amp. averages.

62 K.W. " Integ. Wattmeter --

63 Total K.W. per hour --------------

64 Feed Water, Lbs per hour ---------

65 " mean Temp. Fahr ------

66 Steam Press., average, gauge, ----

67 Total Heat in One Lb. Steam from Feed water Tem. to Steam Temp. --

PLANT RATINGS:

68 K.W.-hours per 1,000 Lbs Feed Water

69 " " " 1,000,000 B.T.U. supplied to the system, ---------

I. - STUDY. Schedule-O.1

1.-Examine, thoroughly, the assigned apparatus, appliance, device, or object of study.

2.-Take apart, disconnect, and note details of construction.

3.-Reassemble, set up, or connect, as originally assigned.

4.-Sketch circuits, arrangements, details, as follows:

(a) All Electrical Circuits.

(b) All Magnetic Circuits.

(c) General arrangements and such details as may be specified; showing plan, elevation, and section, if possible.

(d) Dimensioned sketches of strucutral parts, details as specified.

5.-Measurements and dimensions of structural parts, as specified.

6.-Report on the work done, giving a written account of the same, describing the object assigned for study and explain the uses and functions of its several parts.

(1)-Inspect, thoroughly, the assigned apparatus, appliance, device or other object set apart for such work.

(2)-Take apart, disconnect; re-assemble, set up, or connect as may be necessary for thorough inspection.

(3)-Mechanical Inspection:-Inspect following features and details, in all instances to which they apply:

(a) General appearance and cleanliness.
(b) Freedom of movement of mechanical, electrical, or magnet in mechanisms.
(c) Character of adjustments necessary to operation.
(d) Armatures: clearance; balance,- static, dynamic.
(e) Lining up for operation,-shafts, belting, etc.
(f) Lubrication.
(g) Final adjustments for operation: belt slip, etc.

(4)-Electrical Inspection: chiefly by use of magneto and voltmeter.

(a) Imperfect and loose joints and connections.
(b) Open circuits.
(c) Crosses in circuits.
(d) Grounds,-circuits, armatures, fields, etc.
(e) Short circuits.
(f) Burn outs.

(5)-Magnetic INspection:- chiefly by compas needle.

(a) For magnetization of field, or mechanism.
(b) For direction of magnetic polarity.
(c) For magnetic balance, as in armatures: radial,longitudinal

(6)-Note: For Primary Cells and Storage Batteries; Inspect for

(a) Condition of Electrolyte, quantity, quality.
(b) Condition of electrodes.
(c) State and condition of charge of storage batteries.

(7)-Note: For Dynamo-electric machinery, in particular, as follows:

General:- (a) Sparking at brushes.
(b) Heating: armatures; field coils; bearings.
(c) Noise.
(d) Speed: high or low-
Motor:- (e) Stops; fails to start; direction of rotation.
Dynamo:- (f) Dynamo fails to generate.

See A.I.E.E., -Vol.XI.-1894, Parkhurst's "Diseases of Dynamos."

II. INSPECTION.

Memoranda on Electrical Inspection of Dynamos and Motors

A.-- Electrical Inspection, by Magneto.

1.- Field Frame, simple grounds.

2.- Field Coils, each, individually, (a) open circuits; (b) grounds.

3.- Armatures: (a) closed coil type, inspect for:

(a_1) open circuit.

(a_2) grounds.

(b) open coil type, inspect for:

(b_1) an open coil.

(b_2) crosses between coils.

(b_3) grounds.

B.-- Electrical Inspection, by Voltmeter:

1.- Inspect for short circuits:by millivoltmeter:

(a) in each field coil.

(b) in armature windings.

2.- Locate bad contacts by millivoltmeter.

3.- Inspect for quality of insulation:

(a) for injured or faulty insulation.

(b) for approximate insulation resistance.

(c) for leakage of currentsunder normal conditions.

Note: Voltmeter used to be of high resistance, 15,000 to 20,000 ohms, and adapted to machine circuits, except as noted.

C.-- Inspection for a short circuit, in armature windings:

With fields excited only, rotate armature slowly by hand; mark angular positions, (where torque suddenly increases), to right and left, the short circuited coil is approximately in centre of this arc.

III.-ILLUSTRATION and DEMONSTRATION. Schedule--C.8

1.- Illustration of Electrical and Magnetic Phenomena, singly and in combination.

(a) Electro-Chemical fields, generation, electrolysis, storage, etc.

(b) Electro-Thermal work,-heating effects of currents, calorimetry. lighting by arc and incandescence, electric furnace, etc.

(c) Electro-Dynamic effects, induction, motion, fields of force, etc.

(d) Magnetic phenomena,- fields of force, distribution, strength of fields, useful and waste flux, leakage, magnetization, etc.

(e) Electro-Magnetic phenomena,- induction experiments, establishment of Emf., magnetizing force and ampere turns, elements of dynamo and motor, of various types and windings, etc.

2.- Effects of combinations and limits within which phenomena are available for practical utilization, etc.

3.- Use of instruments,(a) Mechanical; (b) Electrical; (c) Magnetic.

4.- Precautions to be observed:

(a) In handling instruments, - See Instruction Sheets.

(b) In taking observations.

(c) In taking measurements, and use of constants.

(d) In connecting up the work for measurements.

(e) In operating apparatus, machine, etc.

5.- Possible Sources of Errors.

(a) In handling the instruments.

(b) In conncections, etc.

(c) In machine or apparatus used.

(d) In nature of motive power, force, or current used.

(e) In constants used, given or derived.

6.- The Reduction of observations,- use of Least Squares, graphical and analytical methods of stating results, deriving formulae, law constants, etc. See Carpenter's Exp. Eng'g. page 3, etc.

7.- Illustration of fundamental principles, laws, etc.; corroborations.

8.- Illustrat operation of apparatus, machine, etc. (See Operation Sheet)

9.- Characteristics of Performance, constants, etc.

10.- Testing methods, illustrated by typical examples of tests.

11.- How results are discussed and conclusions drawn.

ELECTRICAL ENGINEERING DEPARTMENT.

UNIVERSITY OF ILLINOIS.

II.-OPERATION. Schedule--0.4

1.- Thoroughly clean everything before starting any work.

2.- Examine for any loose parts, fittings, connections, screws, etc.

3.- Fill oil cups and insure good lubrication.

4.- Adjust, line up, tighten belts to ordinary tensions, and make any other preliminary adjustments as may be required by the work.

5.- Have all switches open, cut-outs fused, obstructions cleared, and every freedom of movement necessary for successful operation.

6.-Voltmeter, ammeter, pilot lights, etc. to be used, to watch building up, as of machine, or other line of preliminary operation.

7.- Start up machine or apparatus, as may be necessary.

NOTE: for Dynamos and Motors, see special OPERATION schedule.

8.- Examine functional working of machine or apparatus, for definite result.

9.- Examine performance of machine, etc. as to regulation, control. etc.

10.-Experimentally determine best operating conditions, for highest efficiency, economy, or other feature as may be required in operation.

11.-Coupling, working in parallel, etc.,- mechanically, electrically.

12.-Stopping and disconnecting and cleaning up.

CALIBRATION OF ELECTRICAL INSTRUMENTS AND APPARATUS. Lab.Schedule 0.5
Sheet 1.

References:

Nichols, E.L.; Laboratory Manual, Vol.11.,pp.58-63; p. 196,200.
Holman, S.W.; Discussion of the Precision of Measurements; pp.41-44, pp. 130-38, 96-99;
Fleming, J. A.; Electrical Laboratory Notes and Forms, Nos 5,13,25, 26,28,36.
Instructions for Reduction of Observations, Lab. Schedule 0.55
Instructions for use of Voltmeters, Ammeters and Wattmeters, Lab. Schedules 0.61, 0.62, 0.63.

Object:

To determine the reliability of any given instrument, by comparison of its own readings under different conditions, by comparison with standard instruments.
To determine constants, corrections, coefficients to be applied
To standardize any given apparatus, as a motor, that its performance may be used under similar conditions, to measure the performance of any other machine.
Incidentally to determine best conditions or most accurate methods for use of instruments.

Classification of Calibration Work:

(1) Reliability tests of indicating instruments: Nichols pp. 61-63.
To determine if the needle will come to the same point of the scale each time, under the same electrical supply:
Method: Needle is made to shift from a given position, by a number of different combinations, each time; it should return to the same reading each time the circuit is restored to the original condition, or that which resulted in the given initial reading; failing to do so, there will then be several values for the same initial reading, which may be treated by the method of Least Squares, to find the probable error of a single observation.

(2) Constancy of Zero: Apply preceeding method,zero as initial reading.

(3) Comparison with Standards; or Instruments used as standards:
These may be primary or secondary, and are likely to have inherent sources of errors, noted below under instrumental errors.
Comparisons may be made with auxiliary apparatus, as in use of standardized multiplier to test accuracy of higher scales of a voltmeter, or vice versa; and the use of shunts for ampere readings on milli-voltmeter, testing either the shunt or the instrument, according to which has previously been standardized.

(4) Determination of Constants, as of multipliers and shunts;

(5) Determination of Coefficients, as temperature coefficients. In many cases, from the nature of the material or appliance investigated, such coefficients cannot have a constant value, even if no error be made in the work. In such cases it is necessary to determine the law and cause of such variation; such as calibration of D'Arsonval galvanometer for potential, in which a magnetizing current is used, in which case calibrat ion curves should be obtained for different magnetizing curren

(6) Determination of Corrections: to be made under conditions suited to application or set of conditions determined by practice.

(7) Standardization of Apparatus, as an electric motor: The determination of such performance, as of efficiency, for a standard comparison requires unusual care and the observance of all conditions imposed by calibration work, in general and as noted below, Ordinarily, such determinations are to be made under as nearly as possible the same conditions as in actual practice and application.

Units and Standards; Instruments as Standards:

These require checking or calibration, from time to time. With known constants, corrections and coefficients, it cannot be assumed, without experimental proof, that even the best instruments will remain long without some changes. This is especially true of that class of instruments and standards in which permanent magnets are employed. Note instrumental errors, below.

Sources of Error, in Calibration Work:

(1) Errors in assumptions, such as that in any instrument or a resistance used in experimental work there is neglible self-induction because so considered in ordinary practical use of the same; such an assumption would not be allowed in the most accurate work.

(2) Errors in Conditions, such as not maintaining constant temperature of the room, or compartment where calibration is done.

(3) Errors in variable nature of electrical supply used, as in almost all calibration work, it is necessary to keep potential or current constant. Secure careful regulation by known devices. Also, errors due to variable power in Alt. Cur. Calibrations.

(4) Errors in electrical circuits or connections, which, though correct for the work, may be very poorly made; or being well made may be carelessly handles, for all of which there is no excuse.

CALIBRATION OF ELECTRICAL INSTRUMENTS AND APPARATUS. Lab.Schedule C.5
Sheet 3.

(5) Errors in handling and setting up instruments, whether standards, or instruments being calibrated. No excuse can be offered for these.

(6) Errors in operation of the apparatus, as motor, being calibrated; to be guarded against by intelligent supervision of work.

(7) Instrumental errors: each instrument or piece of apparatus has its own inherent and characteristic sources of error, which may be classified as constant errors. These should be most thoroughly investigated with view to possible removal, wholly or in part. Sources of error not removed should be evaluated and eliminated by applying the corresponding corrections determined in such preliminary evaluation. A modification of the apparatus or conditions of its working may remove several of such constant errors.

(8) Errors of Methods: these must be reduced to a minimum, by studying the very best methods of calibration, and in advance of the work, to ascertain the possible sources of error due to this cause. Then arrange the work or modify the method to remove these errors as much as possible. Evaluate the effects of those sources of error not removed, and afterwards eliminate them by applying the corresponding corrections determined in such preliminary evaluation.

(9) Personal Errors, errors in taking readings, making observations. These are usually constant in amount for any given individual but do not disappear as a result of long continued practice. They should be early recognized; determined, in character, if possible also in amount; and allowed for in giving relative weights to the readings of any given series.

Precautions, all to be observed, as noted in Instruction Sheets for the use of Instruments. Thorough familiarity with the principles and use of the instruments is required.
Note time element(creeping) in alternating current calibrations

Methods to be pursued; in Calibration work:

Ordinary method of calibrating electrical instruments is by direct comparison with standard instruments by measuring some electrical quantity several times and simultaneously by the two instruments. Then a similar series of readings is taken with variable amounts of such electrical quantity, to obtain different points along the calibration curve to be plotted.

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<u>Measurement of Armature Resistances.- Dynamos and Motors.</u> *Lab. Schedule 1.*

Armature resistances can be obtained only when not running.

Method to be used, - Fall of Potential.

Currents to be used, preferably 110 volt circuits; or Battery.

Instruments: low-reading voltmeter, high-reading ammeter.

Precaution: armature must be connected up as a simple resistance, in series, in the circuit being used.

Regulate current used by a water resistance placed in series; or, use a lamp bank, as usual. Use heavy currents.

Take ten (10) consecutive readings of voltage across terminals and of current through armature.

Turn the armature through a small, but different angle, for each consecutive reading.

Take three sets of observations under following conditions:

I. From terminal to terminal, of machine switchboard, not including any series coil connections.

II. From brush to brush, connecting onto clips.

III. From diametrically opposite commutator segments placing voltmeter terminals <u>under</u> brushes.

NOTE:- Measure resistance, cold, at beginning of experiment; that is, before machine is operated or before any field resistances are measured.

Measure resistance hot, after normal running, or after determination of field resistances.

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Lab. Schedule. 2.

Measurement of Field Resistances, ~~--Dynamos~~ and Motors.

Field resistances may be obtained while running at normal voltage, or, when at rest, by use of suitable direct current.

Method to be used,- Fall of Potential.

Instruments, voltmeters and ammeters of suitable ranges.

(I) Resistance of Shunt Coils, of Dynamo.

(1) Use shunt coils only. Run dynamo at usual speed.
Throw in and regulate large resistance in external circuit.
Run out Field Rheostat to end or to the stop.
Short-circuit Rheostat at machine.
Take ten (10) consecutive readings of voltage across shunt and of current through the same.

(2) Use shunt coils and Rheostat. Run at normal speed and voltage.
Take ten (10) consecutive readings of voltage across shunt coils including Rheostat, and of current in same.
Note exact position of Rheostat handle or notch.
Measure exact rrsistance of Rheostat (including its external loads) at formerly observed position or notch.
Resistance of chunt coils- Res. of (shunt and Rheostat) less Res. of the Rheostat.

(II) Resistance of Series Coils of Dynamo.

Poerate dynamo as long or short compound.
Apply fall of potential method as in measurement of low resistances.
Take ten (10) consecutive readings of voltage across series coil and of current in same.

(III) Resistance of Motor Fields.

Proceed as in (II); or, connect ammeter to field coils at motor switchboard, take readings, as before.

NOTE:- Measure resistance, cold, at beginning of experiment. Then measure field resistance, hot, after normal running.

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University of Illinois.

OPERATION of Dynamos and Motors.

In General: Before starting any Machine, attend to the following:

1.-Thoroughly clean everything about machine.
2.-Examine for loose parts, fittings, connections, brushes.
3.-Fill oil cups and insure good lubrication.
4.-Adjust, line up and tighten belts, to rodinary tension.
5.-Have all switches open, and cut-outs fused.
6.-Voltmeter, ammeter, or pilot light in circuit to watch building up of machine, according to circumstances.

I.- DYNAMOS.

A. Starting:

1. Start slowly.
2. Build up the Fields.
3. Examine working, normal, volts.
4. Throw on designated load.
5. Regulate, for Norm. Volts.

B. Operating:

1. Examine for any electrical or mechanical heating.
2. Examine working of belt.
3. Operate as scheduled.
4. Watch against sparking.

C. Stopping:

1. Lower the Voltage.
2. Throw off load.
3. Weaken the fields.
4. Stop prime mover.
5. Lift brushes.
6. Slack belt.
7. Stop oil circulation.
8. Clean machine; and cover.

D. Schedule of Operations.
Shunt Dynamos.

1. Regulate by Brushes.
2. Regulate by Rheostat:
   (a) Vary Emf., const. Load.
   (b) Vary Load, Const. Emf.
   Note: Ammeter readings.
   Direction of Rotation.
   Reverse connections.
   Reverse rotation.

II.- MOTORS.

A. Starting:

1. Excite fields; test same.
2. Start slowly, by Starting Box.
3. Examine working, normal speed.
4. Throw on designated load.
5. Regulate for normal speed.

B. Operating:

1. Examine for any electrical or mechanical heating.
2. Examine working of belt.
3. Operate as scheduled.
4. Watch against sparking.

C. Stopping:

1. Lower ths speed.
2. Throw off the load.
3. Cut-out armature circuit.
4. Weaken fields.
5. Cut-out fields.
6. Lift brushes.
7. Slack belt.
8. Stop oil circulation.
9. Clean machine; and cover.

D. Schedule of Operations.
Shunt Motors.

1. Regulate by starting Box:
   (a) Vary speed, const. Load.
   (b) Vary Load, const. Speed.
2. Regulate by Field Rheostat:
   (a) Vary Speed, const. Load.
   (b) Vary Load, const. Speed.
3. Reg. by Arm. & Field Rheostat.
   (a) Vary speed, const. Load.
   (b) Vary Load, const. speed.
   Note: Ammeter readings, Ext. Cir.
   Direction of Rotation.
   Reverse connections.
   Reverse motor.

OPERATION of Dynamos and Motors, continued. The Ward-Leonard System.

Object.- To operate an electric motor at almost uniform efficiency with ranges of speed and torque.
To secure large starting torque and at the same time high efficiency.

Preliminary.- Make preliminary run at greatest load to ascertain if the machines are adapted to each other and of the proper capacity.

Operate.- Carry through a series of tests to determine data for plotting curves noted below. Operate the motor reversed.

Plot curves, showing characteristic relations between the two assigned variables, on same base where convenient.

Series A. In Illustration of law:
(1) that the speed of motor varies directly as Emf. in usual formula
(2) that the torque of motor varies directly as the armature current, inusual formula.

Series B. The following efficiencies to be determined from net electrical in-put of the motor and measured brake power.
(3) Efficiency at constant speed, on torque base.
(4) Effiency at constant torque, on speed base.

Series C. The following efficiencies to be determined from gross electrical in-put of the system.
(5) Effiency at constant speed, on total watts in-put base.
(6) Effiency at constant torque, on total watts in-put base.

Series D. The following efficiencies to be determined from gross electrical in-put of the system when motor is operated by usual rheostatic control.
(7) Effcy at constant speed, on total watts in-put base.
(8) Effiency at constant torque, on total watts in-put base.

Series E.
(9) Separate aggregate losses of each machine required in the Ward-Leonard system, and plot these and available output on total watts in-put base.

Reference: Transactions of Am. Inst. Elect. Engineers, Vol. XIII, 1896, page 377. "Volts vs. Ohms", by H. Ward-Leonard.

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Lab. Schedule. # 5.

MAGNETIC DETERMINATIONS.

(A) Magnetic Leakage of Dynamos.

Investigate distribution of magnetic flux around magnetic circuit of machine, by means of exploring coils, and ballistic galvanometer or Weston Millivoltmeter.

Precaution:- keep voltmeter away from machine. Use reversing switch; two exploring coils of same resistance.

Wind exploring coils on armature and field. On armature, in neutral plane. On field, in centre of field coil.

Excite field, with steady current, normal excitation.

Use 550 volt supply, with high resistance, in series with the fields to reduce time constant, on 110-volt machine.

Keep armature stationary.

Take three or more preliminary readings, till steady conditions are secured. Take five (5) consecutive readings under as nearly as possible the same conditions, for both armature and field.

Reduce average of five (5) readings to the equivalent reading for one turn, if turns on coil differ.

I. Take ratio of field to armature determination, to get the Leakage Coefficient. Follow Form B.

II. Repeat above series of observations, with increasing values of field excitation, till that for full load is reached, in about five (5) sets of observations.

Plot curves, showing relation between successive values of the Leakage Coefficient, on ampere base line.

(B) Distribution of Waste Magnetic Flux.

Proceed as in previous determinations. Take sets of five (5) observations, at various points along the magnetic circuit.

Reduce these, as before, to equivalent readings, per turn, and determine percentage value of maximum, at centre of field.

Plot, on dimensioned outline drawing of section of machine at right angles to armature, the percentage values of useful flux, laid off normal to centre line, at point of observation.

Discuss determinations and draw conclusions.

MAGNETIC DETERMINATIONS.

(1) Magnetic Leakage of Dynamos.

[illegible] of dynamo, by means of exploring coils, and [illegible] or Weston Millivoltmeter.

Precautions:- Keep voltmeter away from machine.
[illegible]

Wind exploring coils on armature and field. On armature, in neutral plane. On field, in centre of field coil.

[illegible]

[illegible] fields to reduce time constant, on 110-volt machine.

Keep armature stationary.

[illegible] secured. Take five (5) consecutive readings under as nearly as [illegible]

[illegible] one turn, if turns on coil differ.

I. Take ratio of field to armature determination, to get the Leakage [illegible]

II. [illegible] sets of observations.

[illegible] Leakage Coefficient on ampere base line.

(2) [illegible]

Proceed as in previous determinations. Take set of five (5) observations, at various points along the magnetic circuit.

Reduce these, as before, to equivalent readings, per turn, and de- [illegible]

[illegible] off normal to centre line, at point of observation.

[illegible]

Electrical Characteristics of Dynamos.

1. Operating conditions:
   (a) operate assigned machine under the conditions specified in table below for required characteristic.

   (b) Brushes to be adjusted to proper position and must not be shifted during the experiment.

   (c) Field Rheostat to be adjusted to proper position, and not to be changed during experiment, except as required by such specific characteristics as are shown in table below.

   (d) Adjust controlling devices before beginning and do not alter these during the experiment.

   (e) Apply all loads very gradually.

2. Preliminary: take a few preliminary readings to examine the operation of the machine.

3. Instrumental Readings:
   (a) Take readings for all values, constant or variable.
   (b) Take successive readings, by regular instruments, of volts or amperes, according to characteristic being determined.

   (c) Record readings only:
   When conditions are exactly as specified.
   When machine is operating uniformly under steady conditions.
   When constant readings are given by the instruments.

4. Precaution: do not retrace any of the work, even if the reading has not been taken at the exact increment of load intended.

Table of Operating Conditions for Dynamo Characteristics.

Electrical Charadteristics.	Type of Machine.	Posit. of Fd. Rheost.	Fd. Cur.	Ext. Cur.	Tot. Cur.	Emf. Term.	Emf. Tot.	Rpm.	Nichols.II.
Armature.-------	Shunt.	v	V-Y	V.X	v	C	v	C	Exp. 5.
External.-----	Series. Shunt. Comp'd.	c	v	V.X	v	V.Y	v	C	Exp.3,4,6.
Regulation(Ext.)	Sep.Exc.	v	C	V.X	v	V.Y	v	C	
Internal.------ (Mag. Curve).	Series. Shunt.	c	V.X	c	V	V.Y	v	C	Exp.3,4,6.

Letters signify:
- C---values to be maintained constant during experiment.
- c---values which will be constant.
- V---primary variables to be observed and between which the characteristic curve is to be plotted.
- v---secondary variables.

COUPLING. Operation of Direct Current Dynamos and Motors in Series and in Parallel.

A.- General Conditions:

(1) Machines to be of same type, usually of same size.
(2) Compound machines, in general of same type of compound.

B.- Switching-in Conditions:

(1) Direction of current flow should be the same.
Plus to plus for paralleling
Plus to minus for series coupling.
(2) The Emf. or current to be constant and the same, for each machine before switching-in, according to the specific combinations noted in table below.

C.- Operating Conditions:

(1) Speed to be maintained uniform under all conditions.
(2) Equalize or proportion the loads on the several machines by field rheostats or regulators, as case may be.

D.- Operation of Machines, as Coupled:

(1) Operate at different loads, up to maximum for combined output, and examine for satisfactory working.
(2) Where equalizer is used, maintain current in it at a minimum, under all conditions of load, for machines of same size, and note working by an equalizer ammeter.

E.- Unbalanced loads:

(1) Show that a shunt machine in parallel may become a motor if its Emf. be sufficiently lowered; it continues to revolve in same direction, taking current from line.
(2) Illustrate effect of unbalancing three-wire system, by neutral ammeter, and by lamp bank.

Schedule of Operating Conditions and Connections for Coupling.

Machines Coupled.	Conditions.		Connections.		
	Emf.	Cur.	Field.	Armature	Mach. Terminals
1. Shunt: parallel.	same.	Var.	Indep. Excite.	-	To line, in Par.
2. " series, 2w	Var.	same	(a) In series. (b) Indep. Exc.	In series	To line, in Ser. To line, in Ser.
3. series, 3w	same.	Var.	Indep. Excite.		To line, in Ser. neutral between.
Series: parallel 4. with Equalizer	same	Var.	In Par. with Equal. & line	In Par. with Eq. & line	To line, in Par.
5. Mut. Excited.	same.	same.	Each Fd. in Ser. with other arm.		To line, in par.
5a. Series in Series	Var.	same.			
6. Compound: Parallel	same.	Var.	Sh. Ind. Exc. Ser. in Par. Eq. & line.		To line, in Par.
7. Series, 2 w.	Var.	same.	Shunt same as case (2) Ser. Fd. in Ser. with Arm.		To line, in Ser.
8. Series, 3 w.	same	Var.	Indep. Excite. Ser. Fd. in Ser. with arm.		To line, in Ser. neutral between.

Department of Electrical Engineering.
University of Illinois.

Schedule 8.

COMPOUNDING MACHINES.

Objects of Compounding:

(1) To get a flat or over-compound external characteristics at constant speed and under variable loads.

(2) To operate machine at a speed different from that originally intended, necessitated by either belt slip or slight alteration in speed of prime mover.

(3) To compensate for line drop as load increases so as to maintain terminal voltage constant.

Preliminary Data to be obtained:

(1) Number of turns, total, of the shunt field coils.

(2) Speed at which compounding is intended to be effective.

Preliminary Work:

(1) Determine number of shunt turns by comparative method:

(a) Separately excite the machine, use a special auxiliary shunt field winding, and determine the Emf., and field current at normal Rpm., and no load.

(b) Separately excite the machine, using regular shunt field windings, and determine field current at same Emf., as in preceding (a), at normal speed, no load.

(c) Total ampere turns will be same in each case, (a) and (b) preceding. Therefore find the number of turns on the original shunt field winding.

(2) Obtain Armature characteristic for assigned voltage. Determine relation and plot curve between external and field current, operating as a shunt machine, under assigned conditions.

(a) Normal speed, constant voltage.

(b) Normal speed, 5 per cent rise in voltage.

Work of Compounding the Machine:

(1) Compute required turns of series coil from the preceding armature characteristics.

(2) Compensate by a series shunt for 2% variation in speed, from the normal.

Add enough turns to series coil to give desired compounding at speed two per cent below normal Rpm.

(3) Determine proper resistance of series shunt, from predetermined series winding, to give normal compounding at normal speed, and still allow for 2 per cent. variation in speed.

Department of Electrical Engineering.
University of Illinois.

CIRCUIT WORK. Lab. Schedule 61.
Sheet 1.

Object: to make a study and inspection of transmission and distribution circuits, accessories and appliances, examine their electrical and mechanical condition, and make voltmeter measurements of drop and insulation resistance; all with particular reference to the requirements of installation and insurance rules, and the regulations of the National Board of Fire Underwriters, as published in the National Electrical Code.

Inspect the assigned circuits, or parts of the same, noted below:

A. From the generator to the switchboard.

B. Circuits at and on the switchboard.

C. From the switchboard to grounds, for detectors and arresters.

D. From the switchboard to transformer, or to feeders and transmission line, where no transformers are used.

E. At the transformers, at either end of line.

F. The transmission line, or feeder, from switchboard to switchboard or from transformer to transformer.

G. Distributing system, from the distributing point, or transformer to the lamps or motor service; mains and branches.

H. From transformers to ground; grounded secondaries.

Examine one or more of the following features of the circuits, as may be specified or required:

(1) Mechanical imperfections; imperfect or loose contacts, joints, fittings, junctions, connections, etc.

(2) Condition of the electrical circuits; localization of faults:
- (a) Open circuits.
- (b) Crosses.
- (c) Grounds.
- (d) Short circuits.
- (e) Burn outs.

Use magneto and high resistance voltmeter.

(3) Character and condition of accessories and appliances:
- (a) Switches.
- (b) Circuit breakers.
- (c) Fuses.
- (d) Ground detectors.
- (e) Synchronizing arrangements.
- (f) Lightning arresters.
- (g) Instruments and accessories, shunts, multipliers, transform.
- (h) Regulators and compensators.

Note, especially, carrying capacity, kind, type, suitability, operating characteristics, run of circuits, and all details back of Switch Bd.

(4) Condition of insulation, of insulators and of insulating materials used in the constructive work of installation.

(5) Measure insulation resistance of assigned portions; Plate 4.

(6) Measure ground leaks and resistance of grounds.

(7) Make an electrical survey of a district where leakage of current is suspected, resulting in electrolysis of underground pipes for gas, water, etc. Plate 54.

(8) With an Inspector's set, for voltage and wattage measurements, examine lamps throught the distributing system, as specified. If lamps are not all of same rated voltage, determine if proper lamps have been placed at the given point of observation. Also, watts consumed per lamp.

(9) Determine Drop in voltage, as follows:
   (a) At each stage of the distribution, or each portion of the circuit, as may be specified, at assigned loads.

   (b) Examine difference in voltage between any two lamps of the same distributing system or net work: it should not exceed two per cent. of supply voltage.

(10) Determine where subfeeders might advantageously be introduced into the system, if deemed necessary, that a network might be formed:
   (a) In a direct current system.
   (b) In an alternating current system.
   What is the determining factor in each case of network distribution or feeding?

Requirements of Report: Follow Form B., and note following:
(a) Diagram of the circuits examined.
(b) Draw up and fill in an inspection schedule for each circuit or portion of circuit examined, similar to following:

Designation of circuit:
Length of circuit, in feet:
Size of wire used on circuit: (B & S gauge)
Distance apart of wires, of same circuit:
of different circuits:
Resistance of circuit, at given load:
Impedance " " " "
No. of cycles, if A.C. is used:
Volts, at distributing point,
at receiving point:
drop in portion of circuit.
drop, calculated:
drop, in percent of normal:
Amperes, normal, or given load:
Remarks, location of faults, etc.

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University of Illinois.

B. Other Armature Losses,-watts lost in heating armature conductors.

1. Copper (electrical) Losses; proportional to square of current. Measure resistance of Armature. See Lab. Schedule 1.

2. For Induction Motors apply low impressed Emf., for the respective current values (such as required when running at different loads.)
Block the armature.
Measure the watts input.
This will be approximately the Copper loss.

C. Field Losses; watts lost in heating field coils, shunt and series. Measure resistance of fields, See Lab. Schedule 2.

D. Check. - Sum of all of above determined losses should be equal to the watts input, when machine is operated as intended, (shunt or compound), and under same normal conditions, at no load.

If the starting box or field rheostat is used, in the normal operation when determining this check, then the C^2R losses in each must be deducted from the total input to get the net input required to check the sum of all losses.

E. Determination of Efficiency from Stray Power Measurements.

Operate machine as form five to ten successive increments of loads under normal conditions, to get the additional losses in field windings.
Determine the total losses and the efficiencies at the various loads and plot, as per Form G.

Report according to Form H. Plot according to Form G. Insert Losses on Data Form D.

Lab. Schedule 10.

EFFECIENCY DETERMINATIONS.

Determination of Effeciency of Dynamos and Motors by Dynamometer or calibrated Motor.

Precautions.-

Determine under normal speed, volts and current.

Calibrate motor to be of sufficient capacity to drive generator at at fully 25 per cent overload.

Maintain uniform speed through the experiment.

Determine Losses and Effeciency under following Operating Conditions:-

A. -No-load determination of Losses.

Drive machine by external source of power or by calibrated motor, at normal speed, to determine power required as follows

1. Brushes off, to get journal and air frictional losses.

2. Brushes on, no current to get additional brush friction.

3. Separately excited, normal volts, open external circuit, to get additional losses due to hysteresis and eddy currents.

4. Self-excited, normal volts, open external circuit, to get additional losses due to heating shunt field windings.

B.- Range of Loads, to determine Effeciency.

Drive machine by external source of power or calibrated motor at normal speed, to determine power required as follows:

Self-exceied, normal volts; range of loads, from open circuit to 25 per cent. over-load, at from five to ten successive increments at which effeciency is to be determined.

Note:- Report according to Form H; Plot curves according to Form G.

Department of Electrical Engineering.
University of Illinois.

Lab. Schedule 11.

MOTOR-GENERATOR TEST.

Measurement of Stray Power and Efficiency by Motor-Generator Method, of Hopkinson's Circulating Test, based on the assumption that the stray power losses are the same in each machine, which will usually be the case when the condition is fulfilled that the two machines are of the same type and size, and of the same kind of compounding.

Connect the two machines in series, one as a dynamo, the other as motor, and supply loss by auxiliary dynamo.

Operating Conditions:

(1) Uniform speed of dynamo.

(2) Maintain constant potential between the machines.

Preliminary: Run to see if the two machines can be operated together throughout ranges of loads intended.

Measurements: Series of readings from zero to full load.

Precautions:-

(1) Insert fuses in main supply and inter connected circuits.

(2) Note Instructions, of Schedule 7, for the operation of dynamos and motors inseries and in parallel.

(3) Exercise special care in the use and adjustment of the field rheostats and brushes of each machine.

Report:- See requirements, Form B and G.

Department of Electrical Engineering.
University of Illinois.

ARC LAMPS,-STUDY AND ELECTRICAL MEASUREMENTS. Lab. Schedule 12.

Object: to become familiar with the circuits, and operation, and examine "drop" through arc lamp mechanisms.

Study : See "Study" Schedule 0.1. Make Diagrams of circuits and operating mechanisms. Examine lamp, as per following schedule:

(1) Name of lamp.
(2) Kind of lamp, open or enclosed arc.
(3) Kind of service, direct or alternating current, constant current or constant potential.
(4) Driving power mechanism, feeding carbons forward as consumed.
(5) Striking mechanism, to bring together or separate carbons, in starting the ard.
(6) Feeding mechanism, parts by which driving power feeds carbons.
(7) Moderating attachment to prevent too sudden movements of parts.
(8) Replacement mechanism, to allow of re-carboning the lamp.
(9) Focusing mechanism, to keep luminous point in one position.
(10) Change-over mechanism, to bring second pair of carbons into use.
(11) Cut-out mechanism, to complete circuit around lamp, whenever it becomes inoperative.

INSPECTION: See "Inspection" Schedule 0.2.

OPERATION: See "Operation" Schedule 0. 4.

(1) Precaution: use smoked or colored glass in looking at arc.
(2) Preliminary:
    Determine proper direction of current: note crater, if any.
    Adjust controlling devices for regular current value.
    Ensure freedom of movement of all parts, starting, stopping, and feeding mechanisms, etc.
(3) Operation:
    Examine: shape of points, kind of arc (long or short).
    Effect of foreign substances in the arc.
    Effect of using copper coated carbons.
    Rate of consumption of positive and negative carbons.
    Examine functional working of all parts and mechanisms.

ELECTRICAL MEASUREMENTS: See "Meas. of Res"., Lab. Sch. 1,2.

(1) Resistances of parts:
(2) Determine drop in potential through or across parts of lamp: the regulative resistance, mechanism, and the arc, at successive increments of current.
    Determine the counter Emf, of the arc, and watts lost or consumed.

CURVES: Plot the drop in potential through regulative resistance, mechanism, arc, etc, as determined at various increments of current.

References: Nichols, Laboratory Manual, II. Exp. 21, page 46.

ELECTRIC POWER TRANSMISSION. Lab. Schedule 51.

To determine the efficiency and separate the losses at various loads in an electric power transmission, from input, at generating end (engine or dynamo to output of motor.

Case A.-Direct Current Transmission.
Case B.-Alternating Current Transmission without Transformation.
Case C.-Alternating Current Transmission with Transformation.
Case D.-Composite Transmission, Direct and Alternating Current simultaneously on same line.

In transmission by alternating currents, experiment respectively:-

I.-Synchronous working.

II.-Induction Motor working.

III.-Combined synchronous and induction motor service. Performance balanced and unbalanced.

IV.-Synchronous Converter working.

V.-Automatic Regulation of Transmission Line.

Precautions:-

1.-Insert fuses and circuit breakers of proper capacity.

2.-Use instruments whose scales cover all ranges of loads to be experimented with.
3.-Provide for satisfactory and steady working of water-cooled rope brake or cradle dynamometer.
4.-Follow directions for "Operation," Schedule 0.4.

Preliminary:
1.-Make short preliminary run, to examine working of everything.
2.-Run up to specified overload to examine range of rheostats, regulators, instruments, etc., and ensure repeating this at any time, under steady conditions.
3.-Secure operating conditions for best regulation, at normal or specified loads; or determine loads at which best regulation may be obtained.

Observations:-
1.-Take readings simultaneously, by watch or signal only when steady conditions are obtained.
2.-Repeat or take set of readings at initial conditions of each stage of the transmission, for separation of losses.
3.-Take series of readings at successive increments of load, in one direction only.
4.-Do not reverse direction of load changes to repeat any earlier reading.

Plot curves of Efficiency and Separation of Losses, as may be specified, - See Form G, sheets I and 2.

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University of Illinois.

Lab. Schedule. D.C.101.

DISTRIBUTION OF POTENTIAL.

Distribution of Potential to be determined while the machine is in operation, by at least two methods.

Methods to be used:

(1) Mordey's Method, by Pilot brush and Voltmeter.

(2) Thompson's Method, by pair of pilot brushes.

Precautions:

(1) The terminal voltage at dynamo brushes, must be kept constant, as well as the speed and load; lead of brushes fixed.

(2) Thorough contacts must be insured.

Sources of Error:

(1) Due to variable terminal voltage, speed, load, and lead.

(2) Due to imperfect contact of pilot brushes.

(3) Due to hasty averaging of unsteady readings.

Schedule: Make four complete sets of Observations, as follows:-

(1) By Mordey's Method, at no load, normal excitation.

(2) By Thompson's Method, at no load, normal excitation.

(3) By Mordey's Method, at given load.

(4) By Thompson's Method, at given load.

Note:- In Mordey's Method use only a high scale reading voltmeter.
In Thompson's Method, use low scale reading voltmeter.

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University of Illinois.

Lab. Schedule. A.C. 201.

Measurement of INDUCTANCES.- Joubert's method; and Am. & Vm. Method.

Direct comparison, with known or measured non-inductive resistance, in series with inductance to be measured, whose resistance is also known.

Alternating current, approximately sinusoidal; 110 volts.

Measurements:

(1) By direct current, fall-of-potential-method, measure resistances of inductive and non-inductive branches.

(2) With alternating current, measure fall of potential, along inductive E_1 and non-inductive E resistances; and current (I).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.
A.C. voltmeter with negligible inductance.
A.C. ammeter, for current in circuit.

Precaution: currents used must not heat resistances, appreciably.
frequency determinations must be simultaneous with reading of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady, if iron is in circuit.

Take ten (10) consecutive readings for D.C. and A.C. determinations respectively; find arithmetical average and apply Least Squares.

In Joubert's method, apply following formula:

(a) E_1 and R_1 and E and R being respectively, Emf. and resistances of inductive and non-inductive circuits.
f, the frequency.
L, the inductance to be found.

$$\frac{E_1}{E} = \frac{I(R_1^2 + 4\pi^2 f^2 L_1^2)^{1/2}}{I\ R}$$

(b) In Am. and Vm. method, apply formula, as usual, for an alternating current flowing in an inductive circuit, from which the impedance and reactance is to be found, analytically and graphically.

INDUCTANCE of an Alternator Armature.

Alternation armature inductances may be obtained either when the machine is at rest or in motion.

A.-Machine at rest:-

1.-Joubert's method. See Lab. Schedule, A.C.201.
2.-Am. & Vm. method,(Impedance method).Lab. Sch., A.C. 201.
3.-By combination of the two preceding; that is, comparison with known inductance.
Apply formula for comparison of Emf. and impedance, in case of two inductive resistances, in series.

B.-The Emf. of the alternator is to be measured, an open circuit; then with load of known resistance and inductance, measure the armature current, and determine the impedance, and thence the reactance by the usual formula.

RUN.-Alternator on open circuit.
1.-Normally excited.
2.-With non-inductive load of known resistance.
or, 3.-With inductive load, of known resistance and inductance.

Measurements:
1. Measure Emf., at terminals, open circuit.
2. " external circuit current.
3. Determine frequency.

Instruments: A.C. Voltmeter and Ammeter, of suitable ranges.

Precautions:
Maintain exciting current constant.
Operate at constant speed.
Frequency determinations must be simultaneous with readings.
Load must be maintained constant.

Take ten (10) consecutive readings, steady current.

Notes: (1) If armature current does not have too great demagnetizing effect on the field, then the open circuit Emf. of the armature may be assumed to be the same as the total Emf. to be obtained, when the armature is connected up with the external circuit.

(2) Emf. and current curves should be approximately sine.

(3) Armature inductance will then be equal to the difference between the inductance of the entire circuit and the known external inductance.

(4) The inductance of the entire circuit is to be found as usual, by the Am. & Vm. method, applying the formula for the A.C. current flowing in the circuit, from which the impedance and reactance are then to be found analytically and graphically.

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University of Illinois

Lab. Schedule. A.C. 203.

Determination of ANGLE of LAG.

The angle of Lag may be determined from its cosine, by measuring the true watts of the alternating current, and dividing by the apparent watts.

Alternating current: approximately sinusoidal: 110 volts.

Measurements: measure the true energy of the circuit, by wattmeter;
measure the apparent energy of the circuit, by usual A.C. ammeter and voltmeter.

Instruments: A.C. Wattmeter, high resistance, non-inductive.
A.C. Voltmeter, high resistance, non-inductive.
A.C. ammeter.

Precautions: A.C. Wattmeters and voltmeters, must not be used with more than 75% of the maximum allowable scale reading of the pressure coils.
Character of the circuit under examination must not be changed during the time.

Take five (5) consecutive readings, throughout, with three different kinds of inductive loads, in circuit.

Note: If curves of Emf. and of current are at all irregular, then the result found above will be the angle of lag between the equivalent sine curves.
Apply usual methods for analytical and graphical solution.

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University of Illinois.

Lab. Schedule. A.C. 204.

POWER and POWER FACTOR of Alternating Current.

The Power Factor will be determined from the angle of lag, at various loads which are to be measured by the usual methods for determining the true and apparent watts.

Two Methods will be used:

A. By the use of indicating instruments, only.

Follow Schedule A.C. #203, for series of different loads.

B. By the use of Integrating Wattmeters.

(1) Follow Schedule, A.C. #203, for measurements with A.C. ammeter and A.C. Voltmeter of the apparent watts.

(2) Use Integrating Wattmeter of suitable range.

Make a series of runs, at constant loads, for definite time intervals, respectively

Make measurements of Power and determinations for Power Factor by five (5) consecutive readings, at each of five different loads.

In this Experiment, neglect the power consumed by the Wattmeter.

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University of Illinois.

Lab. Schedule. A.C. 205.

Measurement of CAPACITY.- Ammeter and Voltmeter Method.

Direct comparison, with known or measured non-inductive resistance, in series with the capacity to be measured.

Alternating current, approximately sinusoidal; 110 volts.

Measurements:

(1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.

(2) With alternating current measure fall of potential (E_c) across condenser terminals; and fall of potential (E) along non-inductive resistance; and current (I).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.
A.C. voltmeter with negligible inductance.
A.C. ammeter, for current in circuit.

Precautions currents used must not heat resistances, appreciably.
frequency determinations must be simultaneous with reading of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady.

Take ten (10) consecutive readings for D.C. and A.C. determinations respectively; find arithmetical average and apply Least Squares.

In this method apply following formula:

(a) E_c being the condenser Emf. resistance of condenser is zero; E and R being respectively Emf. and resistance of non-inductive portion of the circuit.

$$\frac{E_c}{E} = \frac{I\left\{\frac{1}{2\pi fk}\right\}}{I.R}$$

f, the frequency

k, the capacity to be found.

(b) In this Am. and Vm. Method, apply the formula, as usual, for an alternating current flowing in a circuit containing resistance and capacity, as in this case, from which the impedance and reactance are to be found, analytically and graphically.

A.C. voltmeter with negligible inductance,

Precautions currents used must not heat resistances, appreciably.

Take ten (10) consecutive readings for D.C. and A.C. determinations respectively; then arithmetical average and apply Brooks' formula.

(c) E, being the effective emf,

f, the frequency

L, the inductance to be found.

Department of Electrical Engineering.

University of Illinois.

Lab. Schedule A.C. 206.

INDUCTANCE or CAPACITY in Series and in Parallel.

Determinations of the resultant Emf. (for series combinations) and of the resultant current (for parallel combinations) in circuits containing only:

A.- Inductance; or B.- Capacity.

Alternating current, approximately sinusoidal, 110 volts.

Measurements:

(1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.

(2) With alternating current measure fall of potential (E_c) across condenser terminals; and fall of potential (E) along non-inductive resistance; and current (I).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.
A.C. voltmeter with negligible inductance.
A.C. ammeter, for current in circuit.

Precautions: currents used must not heat resistances, appreciably.
frequency determinations must be simultaneous with reading of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady.

Combinations to be made as follows for each case: A, of Inductances; and B, of Condensers.

I.-

1. In series, without non-inductive branch.
2. In series, with non-inductive branch.

II.

1. In parallel, without non-inductive branch.
2. In simple parallel, with non-inductive branch.
3. In series parallel, with non-inductive branch.

Construct for each case A and B the individual and resultant.

I. Emf. triangles for all series combinations.

II. Current triangles for all parallel combinations.

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University of Illinois.

Lab. Schedule A.C. 207.

INDUCTANCE and CAPACITY in Series and in Parallel.

Determination of the resultant Emf. (for series combinations) and of current (for parallel combinations) in circuits containing both inductance and capacity.

Alternating current, approximately sinusoidal: 110 volts.

Measurements:

(1) By direct current, fall-of-potential method, measure resistance of non-inductive branch.

(2) With alternating current measure fall of potential (E_c) across condenser terminals; and fall of potential (E) along non-inductive resistance; and current (i).

(3) Determine the frequency of the alternating current.

Instruments: D.C. ammeter and voltmeter, for resistance measurement.
A.C. voltmeter with neglible inductance.
A.C. ammeter, for current in circuit.

Precautions: currents used must not heat resistances, appreciably.
frequency determinations must be simultaneous with reading of instruments.
A.C. instruments must not be left in circuit.
A.C. supply to be steady.

Combinations to be made as follows for each case of
A.- Inductance greater than capacity.
B.- Inductance equal to capacity.
C.- Inductance less than capacity.

I.
1. In series, without non-inductive branch.
2. In series, with non-inductive branch.

II.
1. Inparallel, without non-inductive branch.
2. In simple parallel, with non-inductive branch.
3. In series parallel, with non-inductive branch.

Construct for each case A, B and C, the individual and resultant
I. Emf. triangles for all series combinations.
II. Current triangles for all parallel combinations.

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University of Illinois.

Lab. Schedule A.C. 210.

TRANSFORMER OPERATION.

A.- Study of Transformers. See Study, Lab. Schedule 0.1.

B.- Inspection of Transformers. See INSPECTION, Lab. Schedule 0.2, sheets 1 and 2; special inspection by magneto and voltmeter.

C.- Operation of Transformers.- See OPERATION, Lab. Sxhedule 0.1.

1. General condition: Transformers to be of same type and size, and of ratios adapted to combination desired.
2.- Operating condition of a single Tranformer, with divided circuits:
   (a) The primary and secondary coils of transformer to be connected in series or in parallel, as required by its use, and examined by high reading voltmeter, or by two lamps, to determine if Emf.'s have been added or subtracted.
   (b) For Scott Phasing Transformers, connect main and teazer taps, examine main and teazer terminals to determine which of the latter is to be dead-ended.

3. Switching in conditions; of two or more transformers:
   (a) Direction of current flow should be the same; plus to plus for parallel; plus to minus for series coupling.
   (b) The Emf. or current to be the same, for each transformer according to the specific combinations noted in the schedule below.
      Connect primaries, as required by combination being being made; connect one side of each secondary and examine voltage across free ends of secondaries, by high reading voltmeter, or two lamps to determine if Emf.'s have been added or subtracted.

4.- Operating Conditions of Transformers, as coupled:
      Operate at different loads, to the maximum for combined output, and examine heating and regulation for satisfactory working.

5.- Unbalanced loads, on two-circuit, 3-wire systems:
   (a) Illustrate effect of unbalancing, by neutral ammeter or lamp bank.
   (b) Illustrate effect of blowing fuse on one-half of 3-wire system, from a single divided-circuit transformer.

6.- Unbalanced loads on Polyphase circuits.
   (a) Examine effect of unbalanced 2-phase system.
   (b) Examine effect of unbalanced 3-phase system.
   (c) Examine effect of reduced transformer ratio or open circuit in three-phase system.

Note: Primary coils, the small wire high resistance windings.
Secondary coils, the large wire low resistance windings.

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Transformer Operation. Lab. Schedule A.C. 210. (2)

Schedule of Connctions and Combinations.

	Primary Coils.	Second. Coils.	Resulting Ratios, for circuits below: One circuit 2-wire.	Two circuit 3-wire.	Two circuit 4-wire.	Prim. volts
I. Single Transformer:						
Connection #1	Par'l	Par'l.				
#2	Par'l.	Series.				
#3	Series.	Par'L.				
#4	Series.	Series.				
II. Two Trans.						
Combination #1	Par'l.	Par'l.				
#2	Par'L.	Series				
#3	Series	Par'L.				
#4	Series	Series				
III. 2-Phase Trans.						
Combination #1	Indep.	Indep.	2-phase, 4-wire, to 4-wire			
#2	Indep.	Series	2-phase, 3-wire to 3-wire.			
#3	Series	Indep.	2-phase, 3-wire to 4-wire.			
#4	Series	Series	2-phase, 3-wire to 3-wire.			
IV 3-phase Trans.						
Combinations #1	Delta.	Delta.	3-wire system.			
#2	Delta.	Star.	3-wire system.			
#3	Delta.	Star.	3-wire to 4-wire system.			
#4	Star.	Delta.	3-wire system.			
#5	Star.	Star.	3-wire system.			
#6	Star.	Star.	3-wire to 4-wire.			
V. Phasing. Transformers.	3-phase Star.	2-phase Indep.	3-phase Delta.	3-wire Star.	Second	Prim.

Note: In the above combinations, compare the actual with the theoretical ratios of transformation and the Emf. relations in polyphase combinations.

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University of Illinois.

TRANSFORMER TESTING. Lab. Schedule A.C. 211.

A. Resistances of Primary (High Resistance) and Secondary (Low Resistance) Coils.-- See Lab. Schedules 1 and 2, Resist. Meas.

B. Inductance of Transformer and its variations with different degrees of saturation. See Lab. Schedule A.C. 201.

C. Angle of Lag, Power and Power Factor of alternating current through Transformer. See Lab. Schedule A.C. 203, 204.

D. Transformer Testing:
Operating Conditions: Primary voltage must be steady.
Apply all loads gradually on secondary circuit.
Preliminary run to examine operation and range of apparatus.

1. Regulation or External Characteristics:
Readings: Primary voltage, to be maintained constant.
Secondary current and voltage at variable loads.

2. Power Factor Curve: See Lab. Schedule A.C. 204.

3. Loss Curves; to be determined as follows:
(a) Copper Losses, from ammeter measurements and given or known resistances of primary and secondary coils.
(b) Iron Losses, by following readings on open circuit secondary:
(1) ammeter, to correct for small and usually negligible copper losses.
(2) wattmeter, to determine total losses in transformer.

4. Efficiency, to be determined by following methods:
(a) Simple wattmeter method, by simultaneous wattmeter measurements in primary and secondary.
(b) Stray power method, compute the effiency from the above determined copper and iron losses.
(c) Sumpner's circulation method, or Differential method:
Two similar transformers, same type and size.
Primaries of the two transformers shortcircuited on themselves, in series.
Secondary of one transformer, in parallel across the mains; secondary of the other transformer in series with secondary of an auxiliary transformer and a wattmeter, and all three in parallel, across the mains.
Ammeter, voltmeter and wattmeter in maincircuit.

Note: Use Forms, B and G in writing report on above work.

COUPLING (SYNCHRONIZING) ALTERNATORS.

A.C. Schedule 214.
Sheet 1.

A. <u>General Conditions</u>:

(1) Alternators to be of same type and similarly driven by the same kind of prime mover (steam or gas engines, turbines or motors).
(2) Composite alternators to have same type of composite windings.
(3) Circuits from machines to be of same phase, voltage and frequency.

B. <u>Synchronizing Lamps</u>.

Connect for each machine synchronizing lamp or lamps (of total voltage equal to that of each machine) in series with the synchronizing bus bars or in series with similar arrangement at other machine (if there are only two machines to be coupled), with plug or switch to cut out lamps at any time. Total voltage of all lamps in series equal twice the voltage of machines synchronized.
Single phase circuits require only one set of lamps ~~in each phase, unless they~~ arranged, as above described, for each machine.
Two and three-phase circuits, require a set of synchronizing lamps in each phase, unless they have previously been made symmetrical in each phase and the connections for synchronizing thence made permanent.

C. Synchronizing Switch:

Provide synchronizing switch between the leads of the two machines: and if there are more than two machines, such a switch to be provided between machine and bus bar; and, in any case synchronizing switch must throw in all phases at once.

D. Starting:

Machine to be coupled must be driven by independent prime mover and brought up to synchronous speed, usually without load.
Bring up voltage to that of other machine or of the bus bars.

E. Switching-in Conditions, or Synchronizing.

Plug in the synchronizing lamp or lamps for each machine, before synchronous speed is reached.
As synchronous speed is reached, watch when lamps go out.
Throw synchronizing switch during a long interval when lamps are out, at which time the machines are in synchronism.
Machines are usually synchronized with no load on them.

Synchronous Motor Working.

(See Schedule for OPERATION, for all features of work applying to this which are not included in electrical lines of operation.)

A.-Synchronous working, in general, single or polyphase circuits.

I.- Illustration of characteristic features of the operation and performance of synchronous motors.

1.-Show that a synchronous motor, unexcited, will start up, as an induction machine, and attain almost synchronous speed.

2.-Show that by changing the ecitation of synchronous motor, the phase of the line current is shifted, and as follows, for a given of fixed load on the motor:
- (a) Weak field excitation, current lags, large value for work.
- (b) Moderate field excitation, current may be brought into phase with impressed emf., giving unity power factor and minimum line current, and maximum efficiency.
- (c) Stronger field excitation, current becomes leading, and increases in value for given work done.

3.-Show that by changing the load on the synchronous motor, the phase of the line current may be shifted, and as follows, for given degress of field excitation:
- (a) Weak field, motor rather under-excited, power factor simply reaches a minimum, but does not become unity.
- (b) Moderate field excitation, (the most desirable one), the current lags behind impressed emf. at small loads, comes ~~again~~ into phase with it, at about average load, and lags again at heavier loads owning to its leading the imp. emf.
- (c) Strong field excitation, current leads the impressed emf. at all light and moderate loads, passes through zero lag, and them lags more and more; maximum loads.

4.-Show how to hold power factor close to unity, as any load changes, by suitable variation of field excitation.

5.-Show under what conditions current will be leading at lighter and lagging at greater loads than those for unity power factor.

6.-Show that synchronous motor will work, with given output, and at same current, with two different counter emf.'s, in one case with leading and in the other case with lagging current.

7.-Show when an over-excited synchronous motor acts like a condenser on the transmission line, and work it in circuit with an induction motor to raise the power factor of the line.

8.-Show that an overloaded polyphase synchronous motor that falls out of step, can quickly be brought up to speed and into step, by relieving slightly of the load.

A.-Synchronous working, in general, single or polyphase circuits.

II.-Experimental Determination of Machine Characteristics.

1.-Determine if machine has very low armature reaction; that is, good constant potential regulation, by the greater care required in the adjustment of voltage, phase, etc., for throwing in, at any given frequency.

ou If machine has very low armature reaction, short circuit, falling out of s out of step, (due to overload), or opening field circuit will destroy synchronous working of machine.

2.-Determine if machine has high armature reaction, as shown by its behavior in synchronizing; synchronizing power will be greatly reduced, requiring very careful adjustment of driving power, lest it be thrown out of synchronism.

3.-Determine, if synchronous motor, as a generator, has excellent inherent regulation (small armature reaction and self-induction), by experimentally determining if one field adjustment gives practically unity power factor, at all but very light loads; and whether it requires a large starting Cut.

4.-Determine this suitable field excitation, for unity power factor, over wide ranges of load variations.

III.-Experimental Determination of Operating Characteristics.

1.-If motor takes large strating current, try effect of reactance and resistance in main line circuit. At about 50% of impressed Emf., the starting current equals about full load current, and torque then about 15% full load torque; corroborate.

2.-Show how, experimentally, to adjust field excitation, for any given load on any synchronous motor, to get unity power factor at that given load, whether average or full load.

3.-Examine conditions when field strength of two mabhines, equal in all respects, and operated synchronously, is varied, as follows:
(a) Field strength of generator and motor equal.
(b) Field strength of generator greater than motor.
(c) Field strength of generator less than motor.

IV.-~~Starting Operations~~.

1.-Start, with motor in synchronism, at very low speeds, and slowly increase speed of generator, to prevent motor falling out.

2.- By running up to synchronous speed, by driving motor from any source of power, and throwing into line wi h generator when motor is in synchronism, as shown by synchronizing lamps.

SYNCHRONOUS MOTOR WORKING.
(See Schedule for OPERATION, O.4, for all features of work applying to this which are not included in electrical lines of operation).

Illustration of characteristic features of the operation and performance of synchronous motors, single or polyphase circuits.

A. Starting Conditions.

1. Start, with motor in synchronism, at very low speeds, and slowly increase speed of generator, to prevent motor falling out.

2. Start by running up to synchronous speed, by driving motor from any source of power, and throwing into line with generator when motor is in synchronism, as shown by synchronizing lamps.

3. Show that a synchronous motor, unexcited, will start up, as an induction machine, and attain almost synchronous speed.

B. Operating Conditions.

1. Show that by changing the excitation of synchronous motor, the phase of the line current is shifted, and as follows, for a given or fixed load on the motor:

(a) Weak field excitation, current lags, large value for work.

(b) Moderate field excitation, current may be brought into phase with impressed Emf., givingunity power factor and minimum line current, and maximum efficiency.

(c) Stronger field excitation, current becomes leading, and increases in value for given work done.

2. Show that by changing the load on the synchronous motor, the phase of the line current may be shifted, and as follows, for given degrees of field excitation?

(a) Weak field, motor rather under-excited, power factor simply reaches a minimum, but does not become unity.

(b) Moderate field excitation, (the most desirable one), the current lags behind impressed Emf. at small loads, comes into phase with it, at about average load, and lags again at heavier loads owing to its leading the Imp. Emf.

(c) Strong field excitation, current leads the Imp. Emf. at all light and moderate loads, passes through zero lag, and then lags more and more; maximum loads.

3. Show how to hold power factor close to unity, as any load changes, by suitable variation of field excitation.

4. Show that synchronous motor will work, with given output, and at same Arm. current, with two different degrees of excitation, in one case with leading and in the other case with lagging current.

5. Show when an over-excited synchronous motor acts like a condenser on the transmission line, and work it in circuit with an induction motor to raise the power factor of the line.

(Show that an overloaded polyphase synchronous motor that falls out of step, can quickly be brought up to speed and into step, by relieving slightly of the load. 62

Induction Motor Working.

(See Schedule for OPERATION, for all features of work applying to this which are not included in electrical lines of operation.)

A.- Induction motor working, in general, single or polyphase circuits.

1.-Illustration of characteristic features of operation and performance of Induction motors, chiefly of the short-circuited armature type.

2.-Show that large starting currents are required for these.

3.-Show that the slip, in speed, of induction motors, increases with the load applied.

4.-Show that the starting current is reduced by lowering the impressed Emf., and at the sacrifice of starting torque.

5.-Show that in an overloaded induction motor, the speed and torque rapidly fall off, while excessive current is required.

6.-Show when an overloaded motor will stop; how started again?

7.-Show how speed of induction motor may be varied by varying the impressed Emf., by use of an external reactance or compensator on motor possessing high fixed armature resistance.

8.-Show that powerfactor of the circuit, at full load of induction motor, remains practically unchanged with ordinary variations in the impressed Emf.

9.-Show that an induction motor may be advantageously used in connection with a synchronous motor on same line, to reduce power factor, by synchronous motor performance as condenser.

II.- Experimental Determination of Machine Characteristics.

1.-Determine if induction motor has high breakdown point, and at what speed, slip, current, and Emf.?

2.-Determine if the machine requires large magnetizing current, and under what conditions.

3.-Determine what starting loads, and what full and overloads, the give machine is adapted to take, under given conditions of electrical supply, and possible variations in impressed Emf.

Induction Motor Working.

A.- Induction Motor Working, in general, single or polyphase circuits.

III.-Experimental Determination of Operating Characteristics.

1.- Determine starting and acceleration characteristic,-speed and time, for any given load and impressed Emf.

2.- Determine relation of starting current to starting torque at given impressed Emf.

IV.-Starting Operations.

B.-Single Phase Induction Motors.

I.- Starting Operations.

Determine starting characteristics and all features connected with starting, as above noted, in general, for following:

1.-Auto-transformer in starting single phase induction motors.

2.-Phase splitting, by use of resistance and reactance, in external circuit of motor.

C.-Polyphase Induction Motors.

I.-Operating Characteristics.

1.-Open one leg of circuit, while motor is in normal running conditions, and determine following points:

(A) Allow motor to slow down, by opening line switches, close the same, and determine point below which the induction motor, so operated, will not start up again.

(b) Show that the same motor cannot be started up from rest, under these conditions.

(c) Determine slip, current, etc., as detailed above, in general, for the induction motor operated under these conditions, and compare results obtained when motor was normally operated.

2.- Operate polyphase induction motor, as a single or two-phase machine, as a case may be, and compade performance, output, etc., as obtained under normal operating conditions, and as obtained when one leg is thrown out of service.

In this case, cross connect, so as to make use of all coils.

A.C. Schedule 218. - A.

INDUCTION MOTOR WORKING.

(See schedule for OPERATION O. 4 for all features of work applying to this which are not included in electrical lines of operation).

Illustration of operation and performance of Induction motors, chiefly of the short-circuited armature type.

A. STARTING CONDITIONS.

1. Single phase Induction Motors.
   (a) Examine Auto-transformer in starting these motors.
   (b) Examine use of phase splitting, by use of resistance and reactance, in external circuit of single phase motor.
2. Polyphase Induction Motors.
   Examine starting conditions for 2-phase and 3-phase motors.
3. Starting Current and Torque, in general.
   (a) Show that large starting currents are required.
   (b) Show that the starting current is reduced by lowering the impressed Emf., and at sacrifice of starting torque.
   (c) Determine what starting loads, and what full and overloads, the given machine is adapted to take, under given conditions of elec. supply, and possible variations in impressed Emf.

B. OPERATING CONDITIONS.

1. Show that the slip, in speed, of induction motors, increases with the load applied.

2. Show that in an overloaded induction motor, the speed and torque rapidly fall off, while excessive current is required.

3. Show when an overloaded motor will stop; how started again?

4. Show how speed of induction motor may be ~~xxxxxxx~~ varied by varying the impressed Emf., by use of an external reactance or compensator on motor possessing high fixed armature resistance.

5. Show that power factor of the circuit, at full load of induction motor, remains practically unchanged with ordinary variations in the impresses Emf.

6. Show that an induction motor may be advantageously used in connection with a synchronous motor on same line, to raise power factor by synchronous motor performance as condenser.

7. Polyphase Induction Motor. - Open one leg of circuit, motor in normal running conditions, and determine following points:-
   (a) Allow motor to slow down, by opening line switches, close the same, and determine point below which the induction motor, so operated, will not start up again.
   (b) Show that the same motor cannot be started up from rest, under these conditions.

ROTARY CONVERTER WORKING.

(See schedule of OPERATION, for all features of this work which are not included in electrical lines of operation.)

Series A.- Rotary Converter Operated as a Dynamo.- See Schedule 4(1,2).

A.-1- As Direct Current Dynamo.

A.-2- As Alternating Current Dynamo: 1,2,or 3-phase.

A.-3- As Double Dynamo, D.C. and A.C. Output.

Series B.- Rotary Converter Operated as Motor.- See schedule 4(1,2).

B.-1- As Direct Current Motor.
B.-2- As Alternating Current Motor.

Series C.- Machine Operated as a Rotary Converter.

C.-1- Direct Current Motor: Alt.Cur. Dynamo, 1,2,or 3-phase.
C.-2- Alt.Cur. Motor, 1,2,or 3-phase: Direct Current Dynamo.

Schedule for each Series of Operations;

I.-Illustration of Characteristic Features of Operation.

II.-Experimental Determination of Machine Characteristics.

III.-Experimental Determination of Operating Characteristics.

Series.-A.- A-3.- As Double Dynamo, examine especially:

(a) Regulation by brush and by rheostat.
(b) Ratio of A.C. and D.C. Emf.; use Weston Instruments at each end. Compare with Cardew Voltmeter readings.
(c) Determine per cent variation of observed Emf. ratios from the theoretical.
(d) Increased output, over that given by operating as a single machine.

Series B.--B-2. As Alt.Cur. Motor. See Schedule, Synchronous Motor, 215.

(a) Follow schedule 215, for 2 and 3-phase motor working.
(b) Operate specially, as follows:
  I.-Start by using D.C. supply, to bring up to speed.
  II.-Show effect of variation of speed of generator on single or polyphase synchronous working: under what conditions will motor drop out of step.
  If dynamo is momentarily stopped, or switch thrown open for an instant, or motor drops out of step, otherwise by heavy overload: show that it will pick up again when normal running conditions are instantly resumed.
  III. Operate with fixed field excitation: show that power factor and line voltage only slightly changed by variable loads.

Department of Electrical Engineering.
University of Illinois.

A.C. Schedule 220.-2.

Rotary Converter Working.

Series C.- Operation of Machine as a Rotary Converter.

C.-1.- As Direct Current Motor: Alt. Cur. Dynamo.
- (a) Examine starting conditions, polarity of fields, rotation.
- (b) Show that an inductive load thrown on A.C. side, weakens field and machine speeds up.
- (c) Show opposite effect, when synchronous motor is thrown into service, to give leading currents, operating as a condenser on the line.
- (d) Examine effect when induction motor is thrown on the rotary speed and field; on impressed Emf. of motor.
- (e) Show how to secure satisfactory operating conditions of the rotary, whether lagging or leading currents are thrown back into it, on the A.C. side.
- (f) Illustrate regulation of the rotary with lagging or leading currents on A.C. side.

C.-2.- As Alt. Cur. Motor: Direct Current Dynamo.
(See Synchronous Motor Working A.C. Schedule 215.)
- (a) Examine starting conditions, polarity of fields, rotation:
  - (a) As induction motor; (b) Brought up to synchronism as D.C. Motor.
- (b) Examine effect of the performance of the rotary when lagging or leading currents are supplied: respectively:
  - (a) effect on the speed.
  - (b) effect on rotary fields
  - (c) effect on D.C. voltage.
- (c) Examine "pumping" effects:
  - (a) Show that "pumping" is practically constant, for all phases and for all loads, with constant field.
  - (b) Show that the periodicity and amount of pulsation varies with the field: leading currents increasing it; lagging currents decreasing it.
  - (c) Show how to obviate "pumping", by copper bridging, etc.
  - (d) Show effects of line resistance and reactance on pumping, and their value in regulation.
  - (e) Examine so-called "flywheel effects"
- (d) Examine surging of D.C. fields, when rotary is alternately a generator and a motor.
- (e) Examine effects of heavy and variable loads on rotary, as in Street railway working. Show how to build up D.C. voltage under heavy loads.
- (f) Determine best operating conditions for unity power factor.
- (g) Show that the power factor remains practically constant at all loads, in case of shunt wound machines, under best operating conditions.
- (h) Examine effect on regulation, power factor, etc., of compound rotary fields.
- (k) Examine to what extent compounding is desirable, under given conditions of rotary service.

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A.C. Schedule 330.-S.

Rotary Converter Working.

Series C.- Operation of Machine as a Rotary Converter.

C.-1.- As Direct Current Motor: Alt. Cur. Dynamo.
(a) Examine starting conditions, polarity of fields, rotation.
(b) Show that an inductive load thrown on A.C. side, weakens field and machine speeds up.
(c) Show opposite effect, when synchronous motor is thrown into service, to give leading currents, operating as a condenser on the line.
(d) Examine effect when induction motor is thrown on the rotary speed and field; on impressed Emf. of motor.
(e) Show how to secure satisfactory operating conditions of the rotary, whether lagging or leading currents are thrown back into it, on the A.C. side.
(f) Illustrate regulation of the rotary with lagging or leading currents on A.C. side.

C.-2.- As Alt. Cur. Motor: Direct Current Dynamo.
(See Synchronous Motor Working A.C. Schedule [illegible])
(a) Examine starting conditions, polarity of fields, rotation:
(a) As induction motor; (b) Brought up to synchronism as D.C. Motor.
(b) Examine effect on the performance of the rotary when lagging or leading currents are supplied, respectively:
(a) effect on the speed.
(b) effect on rotary fields
(c) effect on D.C. voltage.
(c) Examine "pumping" effects:
(a) Show that "pumping" is practically constant, for all phases and for all loads, with constant field.
(b) Show that the periodicity and amount of pulsation varies with the field; leading currents increasing it; lagging currents decreasing it.
(c) Show how to obviate "pumping", by copper bridging, etc.
(d) Show effects of line resistance and reactance on pumping, and their value in regulation.
(d) ~~Examine~~ [illegible] a generator and a motor.
(e) Examine effects of heavy and variable loads on rotary, as in Street railway working. Show how to build up D.C. voltage under heavy loads.
(f) Determine best operating conditions for unity power-factor.
(g) Show that the power factor remains practically constant at all loads, in case of shunt wound machines, under [illegible] operating conditions.
(h) Examine effects on regulation, power factor, etc., of compound rotary fields.
(k) Examine to what extent compounding is desirable, under given conditions of rotary service.

Department of Electrical Engineering.

University of Illinois.

A. C. Schedule 220.- A.

ROTARY CONVERTER WORKING.

1. As Direct Current Motor; Alt. Cur. Dynamo. See Operation of dynamos and motors, Lab. Schedule 4 (1.2).

(a) Examine starting conditions, polarity of fields, rotation.

(b) Show that an inductive load thrown on A.C. side, weakens field and machine speeds up.

(c) Show opposite effect, when synchronous motor is thrown into service, to give leading currents, operating as a condenser on the line.

(d) Show how to secure satisfactory operating conditions of the rotary, whether lagging or leading currents are thrown back into it, from the A. C. side.

(e) Illustrate regulation of the rotary with lagging or leading currents on A.C. side.

2. As Alt. Cur. Motor: Direct Current Dynamo. (See Synchronous Motor Working, A.C. Schedule 215 A).

(a) Examine starting conditions, ,polarity of fields, rotation:
 (a) As induction motor;
 (b) brought up to synchronism as D.C. Motor.

(b) Examine effect of the performance of the rotary when lagging or leading currents are supplied: respectively:
 (a) effect on the speed.
 (b) effect on rotary fields.
 (c) effect on D.C. voltage.

(c) Examine the so-called "pumping" effects.

(d) Examine effects of heavy and variable loads, on rotary, as in Street railway working. Show how to nuild up D.C. voltage under heavy loads.

(e) Determine best operating conditions for unity power factor.

(f) Show that the power factor remains practically constant at all loads, in case of shunt wound machines, under best operating conditions.

Department of Electrical Engineering.
University of Illinois.

COMPOSITE ELECTRIC TRANSMISSION. A.C. Schedule 221.
Sheet 1.

References: U.S. Patents Nos. 645, 907 and 647, 741 to F. Bedell. El.Wd & Engr., 35:970, 984; 30 June,1900. Editorial and Art. "Copper saving in the joint transmission of direct and alternating currents". -- F. Bedell.

Object:

(1) To transmit electricity by both direct and alternating currents at maintained electrical pressure, over the same system of conductors, and utilize either or both at any point of the line.

(2) To effect saving in copper, for a conductor carrying given A.C. amperes and simultaneously an equal D.C. amperes, has only half as great I^2R loss as though it carried an A.C. or a D.C. equal in amperage to the sum of the given D.C. and A.C. The highest saving in copper or copper loss will be obtained when the D.C. is equal to the virtual value of the A.C.

Essential Conditions: See Plate 49.

(1) The transformers on the A.C. line must have independent primary and secondary circuits.

(2) The D.C. conductor to be connected to neutral point of primary so as to divide the current flow equally in opposite directions through the primary. By such differential arrangement the D.C. exerts no resulting magnetizing influence on the transformer coils.

(3) Where D.C. is to be taken off at any point of the A.C. line, it is necessary to introduce two choking coils, wound on same iron core of low resistance and high self induction, to prevent any appreciable flow of A.C. from one side to the other of the line,but offering inappreciable resistance to the D.C. flow from the same line. This D.C. has no resulting magnetizing effect on the iron of the choke coils, as it passes differentially through them, hence the D.C. does not effect the self induction or choking action of the coils. (See Fig. 1, Plate 49.)

(4) If D.C. is to be introduced into or derived from A.C. system at any point whatever, it should be at corresponding points of A.C. potential. A.C. may similarly be introduced into or derived from a D.C. system at points of equal potential.

Case B.-3. Operation of Sync. Converters, by Composite Trans.

After the machine is brought up to synchronism and thrown into service as a synchronous motor; it may then be operated:
(1) As synchronous converter, receiving D.C., delivering A.C.
(2) " " " A.C., " D.C.
(3) " " motor delivering power at same time.
(4) As composite machine, receiving both A.C. and D.C. and delivering power at same time.

See Rotary Converter Working, A.C. Schedule 220.

Case B.-4. Operating Characteristics of synchronous converter operated as a composite motor. Examine for the same set of conditions as when same machine is operated as a double current generator; namely,

(1) Variable D.C. supply, constant A.C. supply.
(2) Variable A.C. supply, constant D.C. supply.
(3) Variable but equal A.C. and D.C. supply.
(4) Variable but unequal, A.C. and D.C. supply.

11. Comparisons of Simple and Composite Electric Transmission.

(1) Compare the line efficiency and losses and regulation for each system of transmission, with same total energy delivered by the line:
(A) D.C. alone; (B) A.C. alone; (C) D.C. and A.C. same time.
(2) Examine the relation of the voltages D.C. and A.C. of each machine and the line in each, case B.-1 and B.-2.
(3) Show that the voltage delivered to the translating device is not altered by introducing either A.C. or D.C., as in Case A.
(4) Show that equally good working may be had if the A.C. and D.C. are obtained from independent sources, as different machines.
(5) Show that D.C. may be introduced at any point in the A.C. line and without interfering with its operation, may be taken from the same line at any other point; also, that A.C. may be similarly transmitted along a D.C. line; and that in each case A.C. or D.C. or both may be taken off and utilized at any point along such transmission line subject to the conditions earlier given.
(6) Show that "the total I^2R loss of the resultant of these two unlike currents existing simultaneously in one conductor, no matter what their relative value may be, is equal to the sum of the two losses which would be occasioned by the two currents existing separately in the same conductor. "Or", each current undergoes a loss which is quite independent of the other presence and acts as though the other did not exist".
(7) Also, that "the [illegible] is true of the IR drops in voltage set up by the two [illegible]"
(8) Show that "to obtain the highest saving of copper or copper losses the direct current should equal the virtual value of the alternating current."

Apparatus, - Rumford (Lambert) photometer (Palaz, Art. 18 - p. 26)

Two candles.

1. Place the two candles on table in front of screen so that shadows of post fall approximately in the center of screen. Draw No. 1 away until the additional illumination due to it can no longer be detected. Read distances of candles from screen, - d_1, d'_1.
2. Without moving candle No. 2, bring up No. 1 from a distance until the additional illumination is just discernible. Read as before d_2, d'_2.
3. Take as probable true readings $(d_1 + d_2) / 2 = d$, and $(d'_1 + d'_2) / 2 = d'$
4. The sensibility S, is given by $S = (d' / d)^2$
5. Obtain five readings. Reverse position of candles and obtain five more.
6. Get mean of the ten readings and apply least squares.

Tabulate results as below.

No.	d_1	d_2	d	d'_1	d'_2	d'	$(d' / d)^2 = S$	Errors by least squares
1.								
2.								
3.								
4.								
5.								
6.								changed candles
7.								
8.								
9.								
10.								
							mean	probable errors.

Precautions. Candles must be placed directly in front of screen. Keep angles of incidence approximately equal. Take no readings until candles are burning normally. Avoid disturbing the flame by sudden movements, etc. Keep door of room open when not actually reading.

Each member of section must take one complete set of readings and find **S.**

Note:- Calculations are much simplified if d'_1 and d'_2 are always unity.

EXPLANATION OF PLATE 50.

Table of light Ratios for a 300-part Photometer Bar.

This table (Plate 50) gives the ratios of test lamp to the standard when the standard is at the (0) mark and the test lamp at 300. Thus:- If the standard is the Hofner Lamp, 0.87 candles, and the screen stands at 124, the ratio is found by the table to be 2.01 and therefore:

Candle power of test lamp is 0.87 x 2.01 1.75 candles.

If the positions of the standard and test lamp are reversed the ratios will be the reciprocals of those given in the table; or, they may be found by subtracting the reading from 300 and looking in the table for that ratio given for the remainder.

STANDARDIZING METHVEN SCREEN.

REFERENCES.

Palaz. - Arts. 77, 78, 80 - Standard Candles (London).

Art. 96 - Methven Screen.

APPARATUS.

Queen Photometer Bar, Lummer - Brodhun Optical Screen.

PREPARATION.

Test setting of burner for distance and height. Adjust candle for distance and height. Illuminants must be 25 cm. from end of bar and in line with and on level with screen. Light candle and let it burn ten minutes. Snuff to get proper height of 45 mm. Test this with calipers. Set weights leaving candle a little heavy and time when pointer passes zero. Reset weights; (i.e., take off 20 gr. if the run is to be 10 min.). Adjust gas to proper height, (upper set of sights) and take reading during the 10 min. Time end of run (i.e., when pointer again passes zero.)

READINGS.

1. Move screen away from candle until spot disappears. Read (d_1)
2. Approach screen to candle until spot again disappears. " (d_2)
3. Turn screen through 180 degrees and read again (d_3, d_4).
4. Then the probable true setting is given by

$\sqrt{(d_1 + d_2) / 2 \times (d_3 + d_4) / 2} = d$. Get 5 sets of readings; and from table get candle power of each, assuming the candle to be one candle power. (Apparent c. p.)

Corrections. From time of run (i.e. time required to burn 20 gr.) and weight burned reduce the candle to true cp. The true cp. is directly proportional to the consumption of spermaceti if this is within the limits of 114 and 126 gr. per hour. If not, run must be made over again. Get mean of the five readings and apply least squares.

TABULATE thus:

No.	d_1	d_2	d_3	d_4	$d = \sqrt{\left(\frac{d_1 + d_2}{2}\right)\left(\frac{d_3 + d_4}{2}\right)}$	Ap. Cp	Tr. Cp	Mean	Err.

PRECAUTIONS.

If pointer on balance moves slowly notice when edge of pointer comes just in line with edge of mark, placing the ~~edge~~ always directly in front of pointer. Watch gas carefully for proper height. Avoid disturbing candle in any way except when necessary to snuff. Place all trimmings and drip in pan under candle socket. Read only when candle is correct height and burning quietly. Avoid all draughts and other disturbances. Leave door open when reading.

REQUIRED.

Each member of section must take 5 sets of readings. - Do not average readings made by different observers. Original sheet of readings must be handed in with report and description of apparatus used for first time.

NOTE.

Practice reading with the eyes nearly closed. Results will be more accurate and there will be less strain on the eyes. The eyes must be shaded from all light except that of the screen itself.

CHARACTERISTICS OF 50 VOLT INCANDESCENT LAMP.

APPARATUS.

Krüss-Bunsen Photometer. Lummer - Brodhun Optical screen, Von Hefner Alteneck standard (Palaz, Arts. 90-92, See also instructions) 1-1/2 ampere ammeter - 75 Volt Voltmeter.

PREPARATION.

Connect incandescent lamp, ammeter and water rheostat in series on the storage battery. Connect voltmeter across lamp. Mark side of lamp toward screen. Adjust standard and lamp to end of photometer bar, and adjust to correct height using sights on screen - The shadow of sight must fall on centre of spot. Test adjustment of standard.

METHOD.

Adjusting standard to correct height (See instructions) start with a potential across lamp of 55 volts and take a set of readings as follows.

Move screen towards standard till the spot disappears. Read d_1.
Move screen from standard until spot disappears. Read d_2.
Turn screen through 180 degrees and read again d_3, d_4. Then the probable true reading will be given by $\sqrt{d_1 + d_2 /2X (d_3 + d_4)/2} = d$.
Get ratio from table and using value of standard given in instructions get C.p. of lamp. Take readings at 55, 50, 45, 40, and 35 volt

CURVES.

Plot curves between (1) potential and cp. (2) watts and cp, taking cp. as ordinates, and (3) watts per candle and potential, taking watts as ordinates.

TABULATE

No.	d_1	d_2	d_3	d_4	d	ratio	cp.	V.	A.	watts

EMPERICAL FORMULA.

Substitute several values of cp. and volts taken from curve (1) above, in formula:- $cp = C(V)^x$, and find values of x (i.e. with what power of the voltage does the candle power vary)- C (above) = an unknown constant which varies with each lamp.

PRECAUTIONS.

Read only when EMF. and standard are steady. Avoid disturbing flame of standard. Keep room ventilated. Do not keep lamp at 55 volts long. May burn out. Start at highest voltage and come down.

NOTE.

Notice the difference in the tints of the lights at higher voltages. This makes definite readings difficult and is one of the disadvantages of this standard. Observor will find that he can read more accurately if the eyes are partially closed. Will also cause less strain.

Original sheet of readings must always be handed in with report.

The report must contain a description of all apparatus used for the first time.

STANDARDIZING HEFNER LAMP.

Photometry. - 204.
Sheet 1.

REFERENCES:- Palaz. Arts. 31, 78, 80, 85, 90, 91, 93.

APPARATUS:- Bunsen photometer, Hefner lamp, candle balance and standard (English) candle.

METHOD:- Comparison with English candle.

PREPARATION:- Adjust candle and lamp for distance and height, let both burn for ten minutes before making readings. Adjust height of lamp flame, snuff candle to get proper height of flame (45 mm.). Set weights on balance leaving candle a little heavy, and time when pointer passes zero. Remove 20 grs. from beam and time when pointer passes zero again.

PRECAUTION:- Take readings during this time only when the candle and lamp are burning normally and quietly at proper height. Snuff when necessary, placing all trimmings and drip in pan. If consumption of spermaceti is not within limits make a second run.

READINGS:- Take readings as before, bringing the screen up to candle, (d_1) moving screen away from candle, (d_2) turn screen through 180 degrees and read d_3, d_4. Take five sets of four readings each within the ten minutes.

REDUCTION OF OBSERVATION:- To get probable true setting take arithmetical mean of d_1 and d_2;

$$(d_1 + d_2) / 2 = d',$$

and of d_3 and d_4,

$$(d_3 + d_4) / 2 = d'';$$

then take geometric mean of d' and d'', – $d'd'' = d$. From value of (d) get ratio of lights and from consumption of spermaceti find the candle power of candle and of lamp.

TABULATE:-

No.	d_1	d_2	d'	d_3	d_4	d''	d	Ratio

No.	Time.	Consump. of:	True Cp. of:	Ratio:	Cp. of:

Apply least squares and find mean and probable errors in per cent.

REQUIREMENTS FOR REPORT:- Brief description of work. Complete tables with original log and application of least squares.

Example.

No.	d_1	d_2	d_3	d_4	d'	d''	d	Ratio.
1	163	160	151	152	161.5	151.5	156.5	.84
2.	160	163	154	153	161.5	153.5	157.7	.82
3	164	165	147	148	164.5	147.5	156.0	.85
4	159	162	151	147	160.5	149	154.9	.88
5	161	162	148	148	161.5	148	154.8	.88

	Time	Con. Sp.	Time: C.P.	Rat.C.P.of lamp.		Ratio	Do.^{2}
1	9.45	20	1.025	.84	.86	.014	.000196
2				.82	.84	.034	.001156
3				.85	.87	.004	.000016
4				.88	.90	.026	.000655
5				.88	.90	.026	.000655
					874		

Mean Error of Result $= \pm \sqrt{\dfrac{s}{n(n-1)}} = \pm 0.01155 = 1.3\%$

Prob. Error of Result $= \pm 0.6745 \sqrt{\dfrac{s}{n(n-1)}} = \pm 0.0078 = .9\%$

Prob Result $= 0.874 \pm .008$

REFERENCES:- Palaz, Art. 31. Nichols 11. pages, 213, 218, 221.

APPARATUS:- Queen photometer, Ammeter, reading 1 $\frac{1}{2}$ Amp. Voltmeter, reading 75 volts, regulating rheostat.

METHOD:- Comparison with the Methven screen.

PREPARATIONS:- Place lamp in series with ammeter and regulating rheostat across storage batteries, connect voltmeter across lamp. Make connections so as to have all instruments and rheostat close to the standard light (The Methven screen). One observer then has complete control of all apparatus. Test setting of lamps for distance and height. Mark side of lamp towards screen.

RUN:- Start with voltage of 50 (do not go above this) and reading, at 50, 45, 40, 35, and 30 volts, of current, voltage and candle power.

READINGS:- Take readings as before, bringing screen up towards lamp (d_1) moving screen away from lamp (d_2). Turn screen through 180 degrees and read as before (d_3, d_4).

PRECAUTION:- Read only when standard is correct height and burning quietly and voltmeter is steady.

REDUCTION OF OBSERVATIONS:- (1.) To get probable true setting take arithmetical mean of d_1 and d_2, $(d_1 + d_2)/2 = d'$

Then of d_3 and d_4,

$$(d_3 + d_4)/2 = d''.$$

Then get geometric mean of d' and d", $d'd'' = d$.

(2) From the value of (d) get ratio of lights and from candle power of standard get true candle power of lamp.

(3) From ammeter and voltmeter readings find watts input for each E.M.F.

(4) From watts input and candle power find watts per candle power for each E.M.F.

(5). From ammeter and voltmeter readings find resistance of lamp for each E.M.F.

CURVES:- Plot curves between (1). Candle power and E.M.F., (Candle power for ordinates).

(2). Watts and candle power (Candle power as ordinates.

(3). Watts per candle power and candle power (candle power as ordinates).

(4). Ohms and current (Current as ordinates).

TABULATE:-

TABLE NO 1.

No.	d_1	d_2	d'	d_3	d_4	d"	d	ratio	C.P.
1.									

Table NO. 2.

No.	Volts	Amp.	Watts.	Ohms.	Watts per candle	Candle power

REQUIREMENTS FOR REPORT:- Description of the Lummer Brodhun screen. Brief description of the work. Complete tables with original log. Curve sheet with the four curves drawn in ink using curve rules.

DISTRIBUTION OF CANDLE POWER ABOUT AN INCANDESCENT LAMP.

Photometry 306.
Sheet 1.

References. Nichols, p. 214 - 217. Palaz, p. 209.

APPARATUS. Queen Photometer, 2 Voltmeters (ranges: 0 - 75, 0 - 150), 2 Regulating Rheostats,

METHOD. Measure candle power in different directions by comparing standardized incandescant lamp adjusted to give 10 cp.

PREPARATION. Place standard lamp in fixed holder. Connect to storage batteries through regulating rheostat, attach 0 - 75 Voltmeter across standard lamp. Set and keep E.M.F. constant at proper value to give 10 cp. Connect lamp to be tested through a regulating rheostat to storage batteries. Set and keep E.M.F. at normal value.

READINGS. Take readings of cp. every 30° azimuth on each of the following horizontal circles:- Horizontal, 30° above and below; 60° above and below, and one reading, each, 90° above and below.

TABULATE.

Tabulate mean cp. for each direction as below

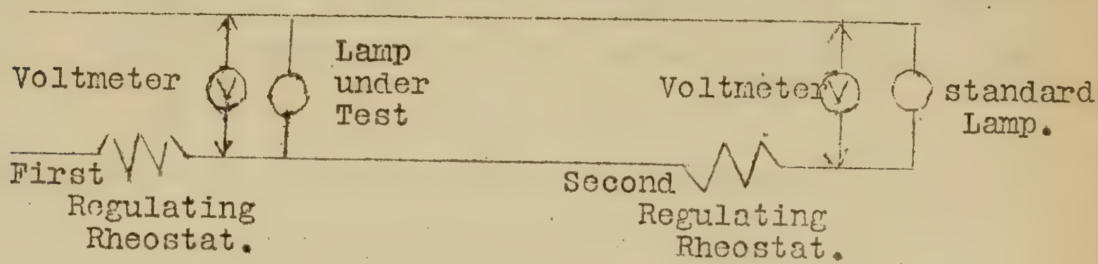
Longitudes:	0	30	60	90	120	150	180	210	240	270	300	330	366
90	One reading only here.												
60													
30													
0													
30													
60													
90	One reading only here.												

81

CURVES. Plot on polar coordinates curve showing distribution in (1), horizontal plane; (2) the vertical plane through filament shanks; and (3) in vertical plane normal to plane of shanks.

REQUIREMENTS FOR REPORTS. Brief description of work, above table complete, three curves and original sheet of readings.

NOTE. By making connections as shown below the work will be much facilitated and slight variations in E.M.F. will not affect results.



The Second Regulating Rheostat is set once for all, and all regulation is effected thereafter by the first rheostat.

CHARACTERISTICS OF SERIES INCANDESCENT LAMP.

APPARATUS. Bunsen Photometer, Standard Lamp, Ammeter (range 0 - 15) two Voltmeters (range 0 - 30, and 0 - 150, two Regulating Rheostats, one with capacity of 6 amp.

METHOD. Measure candle power for different currents by comparison with standard lamp.

PREPARATION:- Connect standard lamp to storage batteries through regulating rheostat. Set at proper E.M.F. to give 10 cp. and keep constant. Connect series lamp on 40 Volt battery circuit in series with ammeter (0 - 15), and regulating rheostat (capacity of 6 amp.). Attach Voltmeter (0 - 30) across terminals of series lamp.

READINGS. Obtain a series of ten readings for different values of current up to 5.5 amp. Read cp., Amp., and E.M.F.

TABULATE.

d_1	d_2	d	ratio	cp.	EMF.	Watts	Rest.

PRECAUTION. Do not carry current above 5.5 Amp.

CURVES. Plot curves between Cp. and Current; Cp. and Watts; Watts per Candle Power and Current; and Resistance and Current. Take for ordinates Cp., Watts per Candle and Resistance.

REQUIREMENTS FOR REPORT:- Brief description of work and discussion of results, complete table, sheet of four curves and original sheet of readings.

REFERENCES. Palaz, p. 17-24. Nichols 11, pp. 215 and 216.

APPARATUS. Queen Photometer, two Voltmeters and Regulating Rheostats

METHODS. (1) From readings obtained in experiment 306 find mean candle power for each latitude and substituting these values in the following formula find mean spherical candle power.

$$M.S.C.P. = \frac{1}{2}\Bigg[\left(\frac{\sin 30^\circ - \sin 0^\circ}{2}\right)(I'_1 - I'_2) + \left(\frac{\sin 60^\circ - \sin 30^\circ}{2}\right)(I'_2 - I'_3) +$$

$$\left(\frac{\sin 90^\circ - \sin 60^\circ}{2}\right)(I'_3 - I'_4) + \left(\frac{\sin 0^\circ - \sin 320^\circ}{2}\right)(I'_4 - I'_5) +$$

$$\left(\frac{\sin 320^\circ - \sin 300^\circ}{2}\right)(I'_5 - I'_6) + \left(\frac{\sin 300^\circ - \sin 270^\circ}{2}\right)(I'_6 - I'_7)\Bigg]$$

(2) Fix lamp in revolving holder and drive by small motor. Keeping potential constant at normal value take readings of candle power in the following directions:- In the horizontal plane, 30° above and below, 60° above and below, 90° above and below.

Substitute in above formula for mean cp.

(3). Take readings of candle power, as follows; (See Nichols.)

Mean of four readings at intersections of V. circles. (N pole)1

Four measurements on each of the vertical.

circles 0° and 90° azimuth, at 60°, 120°, 300° V.__---------8.

Four measurements on each of the vertical

circles 0°, 45°, 90°, 135° azimuth at 30°, 150°, 210°, 330° V -16

Twelve measurements 30° apart on equator ---------------- 12

One measurement (zero) at intersection

of vertical circles, 270° V. (S pole). ---------------- 1

38

Find M. S. C. P. by taking average of above readings. Brief description of work.

REQUIREMENTS FOR REPORT. - Values of M.S.C.P. found by such of the above methods as may be assigned, tabulated readings, original sheet of readings. Discuss the comparative values of the above methods.

USE OF LENSES.

REFERENCES. Palaz. p. 54 et seq.

APPARATUS. Bunsen Photometer, lens of known focal, Voltmeter regulating rheostat and high candle power lamp.

METHOD. (1) Compare lamp with standard directly.

(2) Place lens between lamp and screen and compensating glass plate between standard and screen and measure candle power of lamp for different position of lens.

READINGS. Take readings of candle power of lamp (keeping voltage constant) for three positions of each of the three lenses

FORMULA.

$$I = I' \left(\frac{d + \frac{\delta p}{f}}{d'} \right)^2$$

d = distance from lamp to screen.

d' = " " standard to screen.

δ = " " lens " "

p = " " lamp to lens.

f = focal length of lens.

REQUIREMENTS FOR REPORTS. - Brief description of work, compare the values found and state which you think are the most accurate giving reasons. Tabulate values of candle power found thus:-

No.	f.	cp.

OPTICAL EFFICIENCY OF AN INCANDESCENT LAMP.

Photometry 310.

REFERENCES. Palaz. - p. 262. Nichols. p. 322.

APPARATUS. 0 - 75, Voltmeter, 0 - 1-1/2, Ammeter, Thermometer, glass jar.

METHOD. Calorimetric:- Fill jar with known weight of clear water and determine the temperature. Introduce lamp (in a water proof socket) into water, noting time. Keep E.M.F. and current as constant as possible. Do not stir water except just before taking a reading of temperature.

READINGS. Keep log of readings as shown below; - make three determinations, one each at 40, 45, and 50 volts, or 90, 100 and 110.

REDUCTION OF OBSERVATION:- From E.M.F. and current find total output in Watts. From rise in temperature and weight of water find B.T.U. (heat output = W'). Reduce this latter to Watts = W_1.

Then $W - W_1 = W_{11}$ = Watts light output and

$\frac{W_{11}}{W}$ = Optical Efficiency.

LOG.

Time	Volt.	Amp.	Watts W	Temp.	Watts heat W_1	Watts light W_{11}	Opt. Eff. W_{11}/W

REQUIREMENTS FOR REPORT. - Above LOG, complete, for three values of E.M.F. Discussion of results and of the method of obtaining them Original sheet of readings.

REFERENCES. Palaz, Sec. 144, 145, 147. Nichols 11. Exp. 4, p. 221.

APPARATUS. Kruss-Bunsen Photometer, Bunsen Screen, Lens and Revolving mirror, 15-Amp. Ammeter, two 150-volt voltmeters, standard incandescant lamp, arc lamp, and regulating rheostats.

METHOD. Place arc lamp in a plane normal to photometer bench through centre of mirror, set mirror to desired angle and adjust arc vertically until the oval reflector is concentric with screen and arc known constant distance from mirror. Keep E.M.F. and current constant at during experiment by adjusting water rheostat and length of arc. See that lamp is burning properly (at top).

READINGS. Set screen so that the two sides appear equally illuminated and read (d_1), reverse screen and find new setting (d_2). Then $d = \sqrt{d_1 d_2}$. Find three values for d for each point of arc and take mean. Find candle power every 30° above horizontal (i.e. when arc is below), in the horizontal and every 15° below the hor.

CURVES. Plot on polar co-ordinates angles and candle power.

M.S.C.P. Substitute in the following equations and take 1/2 sum as M.S.C.P.

For upper half: $0.250\,(I_1 - I_2) + 0.183(I_2 - I_3) + 0.067(I_3 - I_4)$.

For lower half: $0.129\,(I_1 - I_2) + 0.120(I_2 - I_3) + 0.103(I_3 - I_4)$
$+ 0.079(I_4 - I_5) + 0.05\,(I_5 - I_6) + 0.017(I_6 - I_7)$

APPROXIMATE METHOD. Substitute in the following formula (Palaz 240) and compare result with that obtained above.

$$M.S.C.P. = \frac{H}{2} - \frac{M}{4}$$

H = Horizontal Intensity.
M = Maximum Intensity.

REQUIRED IN REPORT. Tabulated readings and values, curve sheet, M.S.C.P (both methods), original sheet of readings, discussion of work.

VARIATION OF LUMINOUS INTENSITY OF AN ENCLOSED D.C. ARC LAMP WITH THE INCLINATION.

Photometry. - 312.

APPARATUS. Bunsen Photometer, Revolving Mirror and Lens, 15-Amp. Ammeter; two 150-volt Voltmeters, Standard Lamp, Regulating Rheostat and Enclosed Arc Lamp.

METHOD. Proceed as in experiment 311. See that the lamp is burning properly and that current and voltage are constant during experiment.

READINGS. Take three readings for every 15° in the vertical plane, from 90° above to 90° below the horizontal.

CURVES. Plot on polar co-ordinates angles and candle power (using for candle power the mean for each angle).

REQUIRED IN REPORT. - Tabulated readings and original log, Curve sheet and a brief comparison of the relative advantages of open and enclosed arc lamps as shown by this and the preceeding experiment.

VARIATION OF LUMINOUS INTENSITY OF A.C. ARC LAMP WITH THE INCLINATION.

REFERENCES. Palaz. Sec. 152.

APPARATUS. Queen Photometer and Revolving Holder, Lens, 15-Amp. A. C. Ammeter, 150-Volt A. C. Voltmeter, 150-Volt D. C. Voltmeter, Standard Lamp and Regulating Rheostats.

METHODS. Adjust lamp for proper distances and arc for height. Set carbons vertical and note angle. Revolve lamp in holder to desired angle. Keep current at 8 Amp. and voltage at 35 Volts during experiment.

READINGS. Take three readings for every 15° in the vertical plane, from 90° above to 90° below horizontal.

CURVES. Plot on polar co-ordinates angles and candle power (using for candle power mean for each angle).

REQUIRED IN REPORT. - Tabulated readings and original log, curve sheet and a brief comparison of A. C. and D.C. arcs as shown by this and experiment 311.

Department of Electrical Engineering.

University of Illinois.

Abbreviations.	Titles of Periodicals.
A.E., or Am.El.----	American Electrician. N.Y. (m)
A.I.E.E. ----------	American Institute Electrical Engineers. Transactions.
Am.Jour.Sc.---------	American Journal of Science. New Haven, Ct., (m)
A.A.A.S., or Am.Assn.Proc.----	American Association for the Advancement of Science.
Comp. Rend.---------	Comptes Rendus de l'Acad. des Sciences. Paris. (w)
Ec.El.--------------	L'Eclairage Electrique. Paris. (w)
El.Engr.------------	Electrical Engineer. N.Y. (w)
E.T.Z.--------------	Elektrotechnische Zeitschrift. Berlin. (w)
E.W.----------------	Electrical World. N.Y. (w) (Old name)
E.W. & E.-----------	Electrical World and Engineer. N.Y. (w)
L.E.----------------	Electrician. (London) (w)
L.E.R.--------------	Electrical Review. (London). (w)
J.F.I.--------------	Journal of the Franklin Institute. Philadelphia. (m)
J.I.E.E.------------	Journal Institution of Electrical Engineers.
J.S.T.E.------------	Journal Society Telegraph Engineers. (Old name)
Sc.Abs.-------------	Science Abstracts. London. (m)
Sib.Jour., or S.J.E.------------	Sibley Journal of Engineering. Ithaca, N.Y. (m)
Tech. Quart.--------	Technology Quarterly, Boston.
Phys. Rev.----------	Physical Review. N.Y. (m)

Titles of Books.

Abbott.-------------	Electrical Transmission of Energy. A. V. Abbott.
Cr. & Wh.-----------	Practical Management of Dynamos and Motors. Crocker & Wheeler.
Fleming.------------	Electrical Laboratory Notes & Forms. J. A. Fleming.
Jackson.------------	Alternating Currents and Alternating Current Machinery. D. C. & J. P. Jackson.
Nichols.------------	Laboratory Manual. Vo. II. E. L. Nichols.
Palaz.--------------	Industrial Photometry. A. Palaz.
Par. & Shd.---------	Shop and Road Testing of Dynamos and Motors. Parham & Shedd.
Stine.--------------	Photometric Measurements. W. M. Stine.
Thomp.--------------	Dynamo-Electric Machinery. S. P. Thompson.
Thomp. Poly.--------	Polyphase Electric Currents. S. P. Thompson.

Department of Electrical Engineering.
University of Illinois.

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No.
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Thomp. Polyphase, 81, 88-94, 97-99; Nich. 8, 30; Par. and Shd. 250, 260.
0.2 Inspection, of Machinery and Appliances.
A.I.E.E. 11:939; 12 : 250; Abbott, §§ 241, 248, 249, 256, 258, 259, 264; Nichols 8, 89; Flem. Lab. Notes. Nos. 29, 34; Par. and Shd. pp. 148, 151, 152, 200, 241, 242, 272, 466;; Thomp. 6th Ed. 752, 772, 773-777; Am. El. 8 : 232, Nov. 96; 8 : 265, Dec '96; 8 : 275, Dec. '96; 11 : 417, Sept. '99; E.W. digest, 31 : 365, 19 Mch. '98; E.W.-E. Digest 35 : 225, 10 Feb. '00; E.W.-E, 33 : 407, Apr. '99; E.T.Z. 21 : 38, 11 Jan. '00; L.E.R., 25 Feb. '98.
0.3 Illustration and Demonstration.
Flem. Lab. Notes No. 30; Nichols 45; Par. and Shd. 242 : 3; El. Eng. 25 : 511, 12 May '98.
0.4 Operation of Electrical Machinery and Appliances.
E.W. 27 : 57, 11 Jan. '96.
0.5 Calibration of Electrical Instruments.
Abbott 273-9, 283-4, 285; Flem. Lab. Notes No's. 5, 13, 25, 26, 36; Jack. 133-135; Nichols, 196, 200; E.W. + E. 34 : 305, 26 Aug. '99; Phys. Rev. 6 : 257, '98.
1 Measurement of Armature Resistances.
Abbott §§ 256-257; Flem. Lab. Notes No. 23; Nichols 71.
2 Measurement of Field Resistances.
Nichols 71.
4 Operation of Dynamos and Motors.
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5. Magnetic Determination, Leakage, Waste Flux.
A.I.E.E. 16 : 481, Oct. 99; J.I.E.E. 18 : 617, '89, 19 : 122, Feb. '90; J.S.T.E. 15 : 551; Jackson 233-34; Nichols 67, 70; Thomp. 6th. Ed. 150, 151, 153, 155; E.W. 19 : 11, 12 Jan. '92; 20 : 180, 17 Sept. '92; E.T.Z. 13 : 67; L.E. 24 : 424, 44 : 323, 29 Dec. '99; 44 : 214, 8 Dec. '99; 23 : 121, 17 June '89. L.E.R. 30 : 487, 1892; Tech. Quart. 4 : 205, 3 Oct. '91.
6. Electrical Characteristics of Dynamos.
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7. Coupling Direct Current Dynamos.
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8. Compounding Machines.
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9 Stray Power Determinations.
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10 Efficiency Determinations.
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11 Motor Generator Test.
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12 Arc Lamp Study and Measurements.
Nichols 46.

51 Electric Power Transmission.
Thomp. Polyphase, 62 - 67.

0.61 Circuit work.
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101 Distribution of Potential.
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Alternating Current Work.

201 Measurement of Inductances.
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202 Inductance of Alternator Armature.
Nichols 113, 114, 118.

203 Determination of Angle of Lag.
Jack.111; Nichols 133.

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204. Power and Power Factor of Alternating Currents.
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205 Measurement of Capacity.
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206 Inductance or Capacity, in Series and in Parallel.
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Nichols 174, 178; Am. El. 10 : 85, Feb. '98; 10: 125, Mch, '98; 10: 172, Apr. '98; 10: 222, May '98.

210 Transformer Operation.
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214 Coupling Alternators. Synchronizing.
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303 Characteristics of 50 volt Incandescent Lamp.
Flem. Lab. Notes. No. 14; Nichols 218-21; Stine 70-78, 203-204; E.W.-E Digest 34 : 750, 11 Nov.'99. SCi.Abs.1217, Nov.'98; 480, Feb.'00.
304. Standardizing Hefner Lamp.
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305 Characteristics of Incandescent Lamp.
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306 Distribution of Candle power about an Incandescent Lamp.
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307 Characteristics of Series Incandescent Lamp
308 Mean Spherical Candlepower.
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309 Use of Lenses.
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310. Optical Efficiency of an Incandescent Lamp.
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311 Mean Spherical Candlepower of a Direct Current Open Arc Lamp.
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312 Variation of Luminous Intensity of an Enclosed Direct Current Arc Lamp with the Inclination.
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313 Variation of Luminous Intensity of Alt. Cur. Arc Lamp with Inclination.
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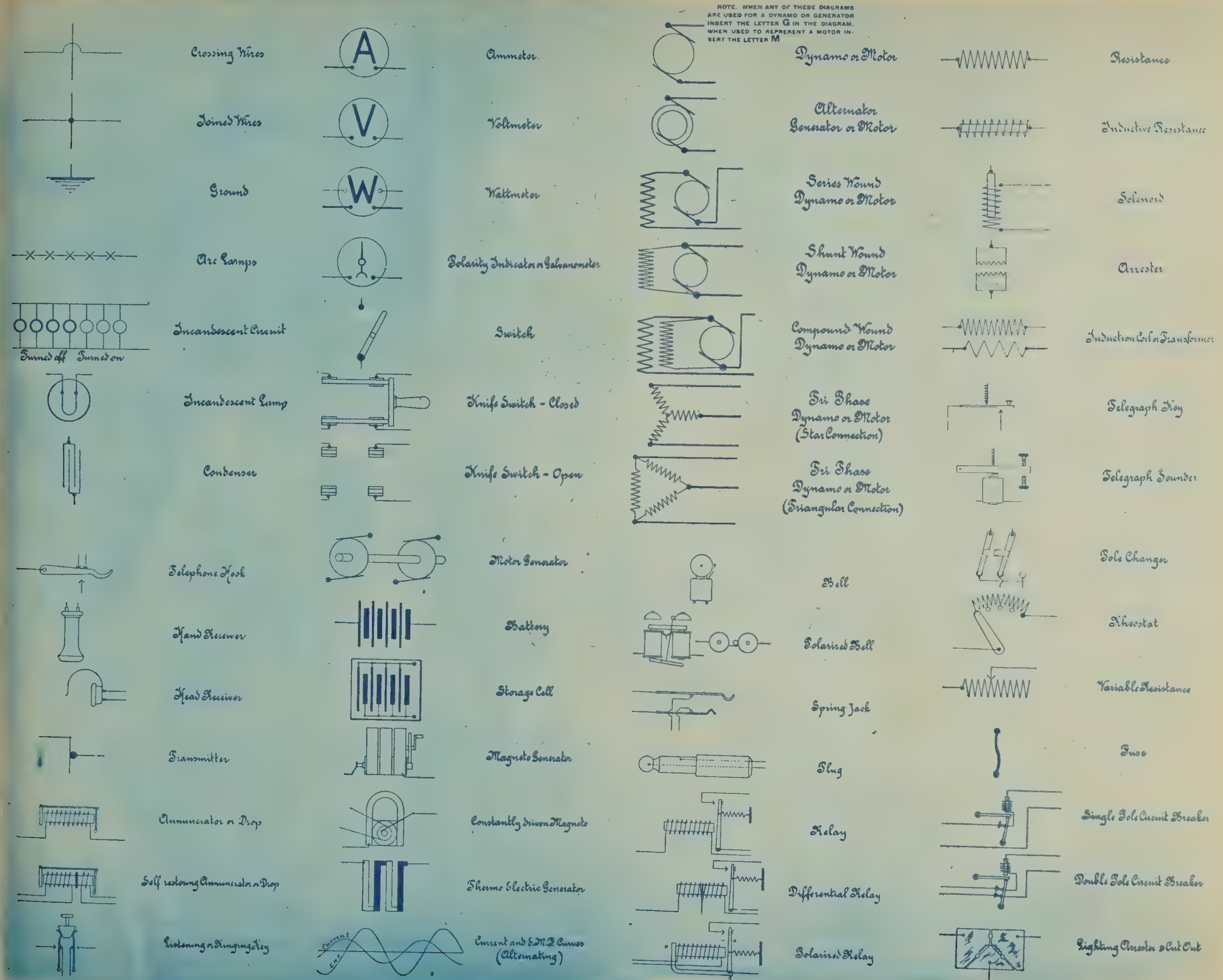
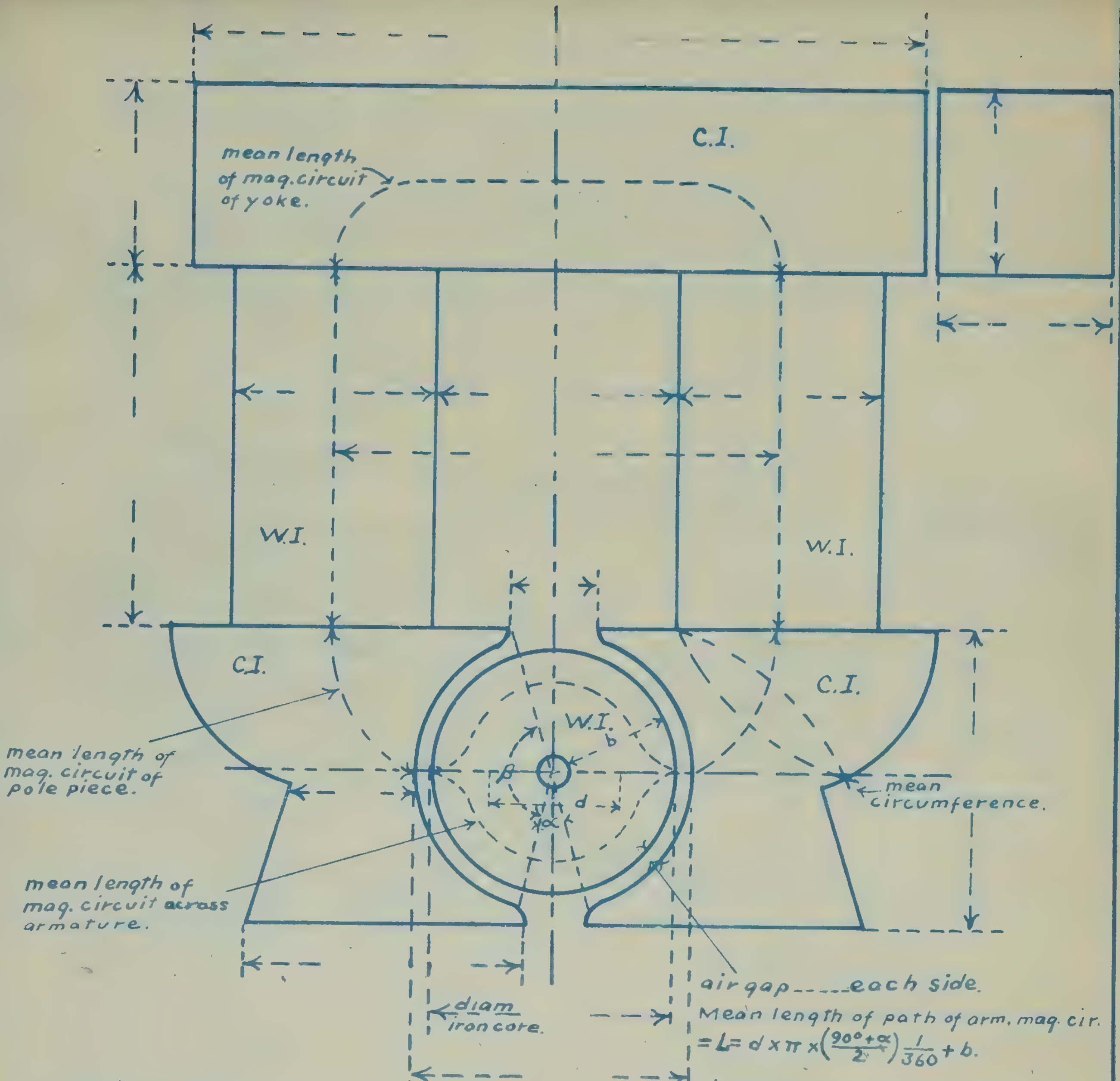


PROPOSED STANDARD DIAGRAMS OF ELECTRICAL APPARATUS.

1



$= L = d \times \pi \times \left(\frac{90° + \alpha}{2}\right) \frac{1}{360} + b.$

d = mean diam. of arm. core.
b = radial depth of arm. core.

Length of Arm. Core ----------

Apparent Core Area --------

True (effective) Core Area --------

Mean sectional area of pole piece ------

Pole Arc: circumferential length. ------

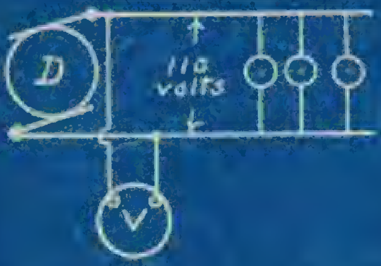
Pole Arc: Axial length. ---------

Pole Arc: Area -------------

EDISON BIPOLAR TYPE DYNAMO.

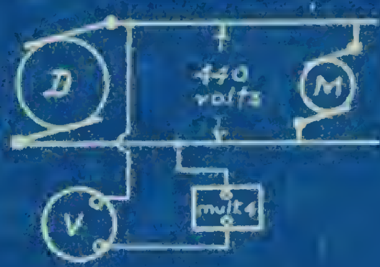
Diagrams of Connections for Laboratory Instruments.

Fig. 1.



Voltmeter on 110-volt circuit.

Fig. 2.

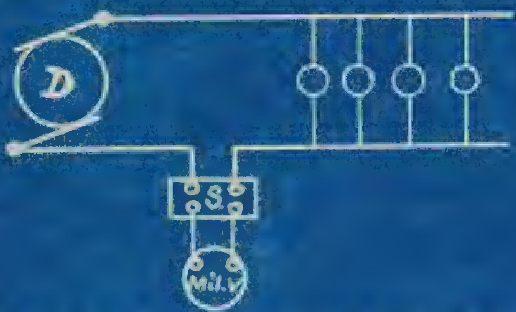


Same voltmeter with multiplier for 440-volt circuit.

Fig. 3.

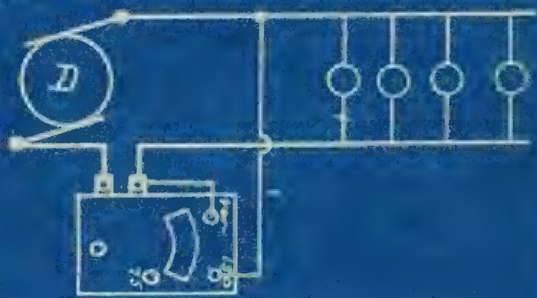
Simple Ammeter Connections.

Fig. 4.



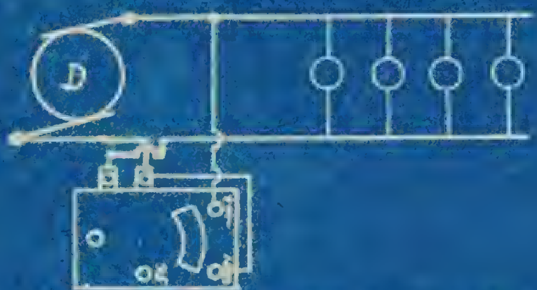
Millivoltmeter as Shunt Ammeter.

Fig. 5.



Standard Connections for Indicating Wattmeter.

Fig. 6.



Indicating Wattmeter Connections. Short pressure wire to other terminal.

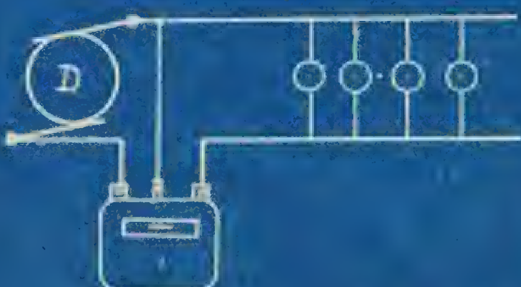
Fig. 7.

Indicating Wattmeter with multiplier. Neglect to place Mult. in circuit will result in burn out of instrument.

Fig. 8.

Wattmeter short-circuited for heavy starting currents. e.g. Ind. motor.

Fig. 9.



Recording Wattmeter Connections.

A. Measurement of Low Resistances, - Armatures, Transformer Secondaries, etc.

Fig. 1.

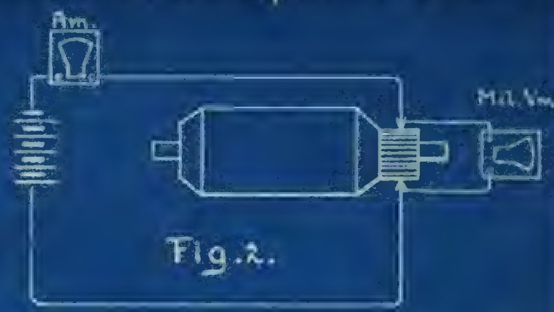


Fig. 2.

A_1 - Resistance to be measured, inserted in series in external circuit of 110 volts from dynamo.

A_2 - Resistance to be measured in series with suitable battery current.

B. Measurement of High Resistance, - Shunt Fields, Transformer Primaries, etc.

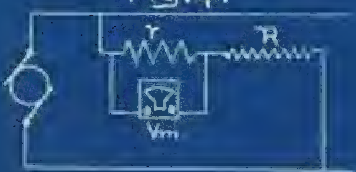
Fig. 3.

Simple 110 volt circuit may be used.

II. Measurement of Resistance by Comparative Methods.

A. Meas'd by Vm alone Compared with known Res.

Fig. 4.



$$R = r\frac{V}{V'}$$

where R = unknown res.
r = known res.
V = Vm reading, Vm in shunt with r.
V' = Vm reading, Vm in shunt with R.

B. Measured by Vm. alone.

Fig. 5.

$$R = r\left(\frac{V - V_1}{V_1}\right)$$

where R = unknown res.
r = res. Vm.
V = Vm reading switch closed.
V_1 = Vm reading switch open.

C. Meas'm't of Insulation resistance.

Fig. 6.

$$R = r\left(\frac{V - V'}{V'}\right)$$

where R = res. insulation.
r = res Vm.
V = diff. in potential betw. two sides of line.
V' = diff. in pot. betw. either side of line and ground.

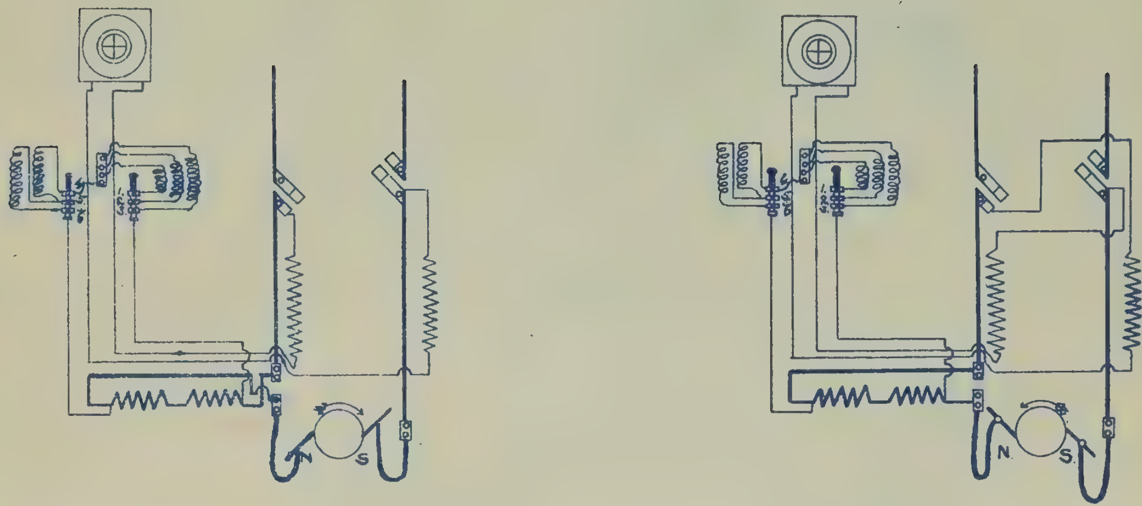
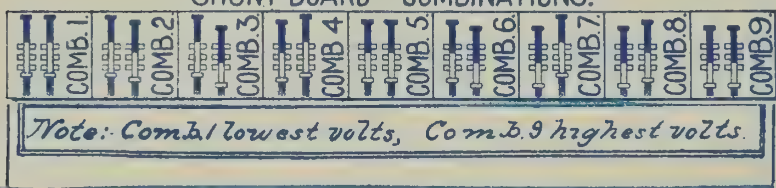
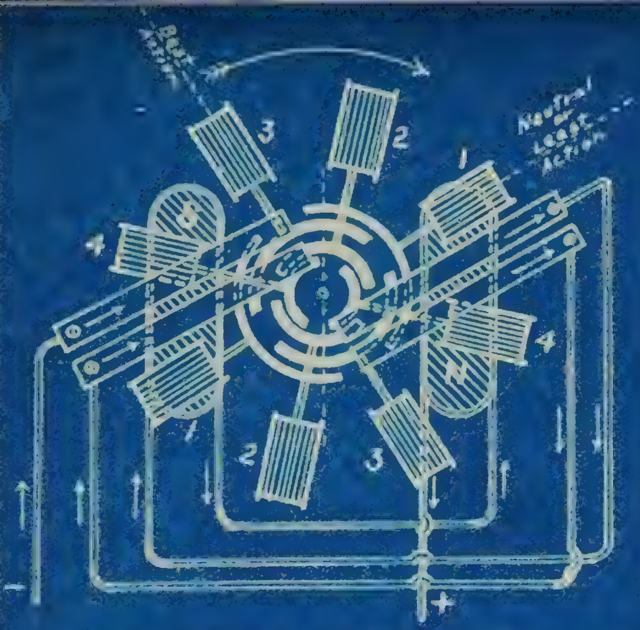


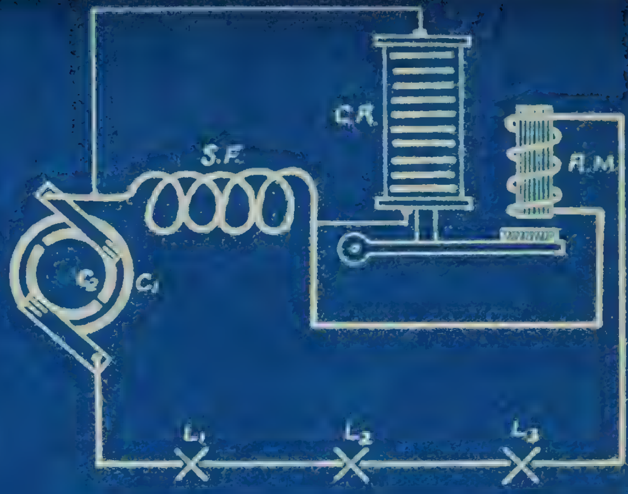
Diagram of Connections for
Compound Dynamos
Edison General Electric Co.

SHUNT-BOARD COMBINATIONS.



Com. 1,	1",2" & 3"	coils	in Mult. 4" & 5" cut out
" 2,	2" & 3"	"	" " " " " " "
" 3,	3	"	only in circuit
" 4,	1",2" & 3"	"	in Mult. 4" in series 5" cut out
" 5,	2" & 3"	"	" " " " " " " "
" 6,	3"	"	and " " " " " "
" 7,	1",2" & 3"	"	in Mult. 4" and 5" in series
" 8,	2" & 3"	"	" " " " " " "
" 9,	3"	"	and " " " " "

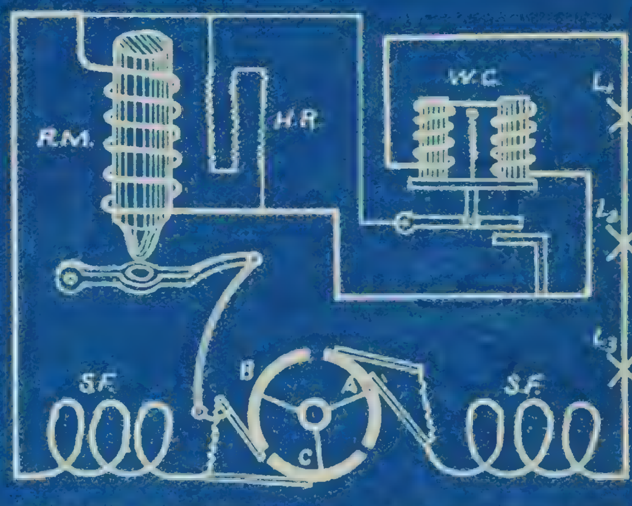




Control by shunting portion of current from field coils when lower EMF is required.

Armature Connections and Regulating Mechanism for Brush Arc Light Machine.

C_1, C_2. First and Second Commutators.
S.F. Series Field.
C.R. Carbon Resistance.
R.M. Regulating Magnet. L_1, L_2, L_3, Lamps.

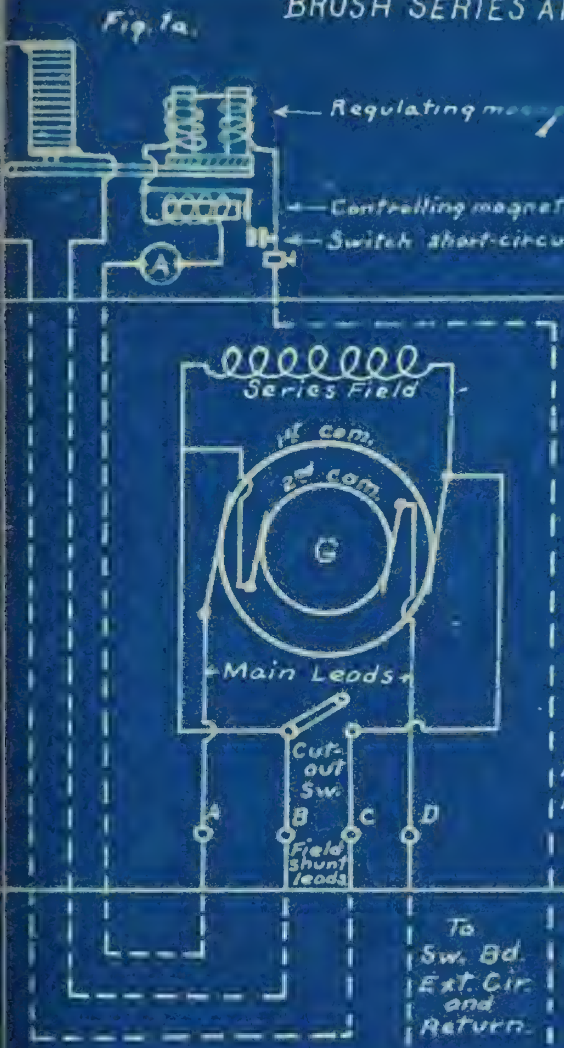


Control by shifting points of commutation of two brushes forming a pair, respectively, on each side.

Armature Connections and Regulating Mechanism for Thomson-Houston Arc Machine.

R.M. Regulating Magnet.
H.R. High Resistance Shunt.
W.C. Wall Controller.
S.F. Series Fields.
L_1, L_2, L_3, Lamps.

BRUSH SERIES ARC MACHINE.

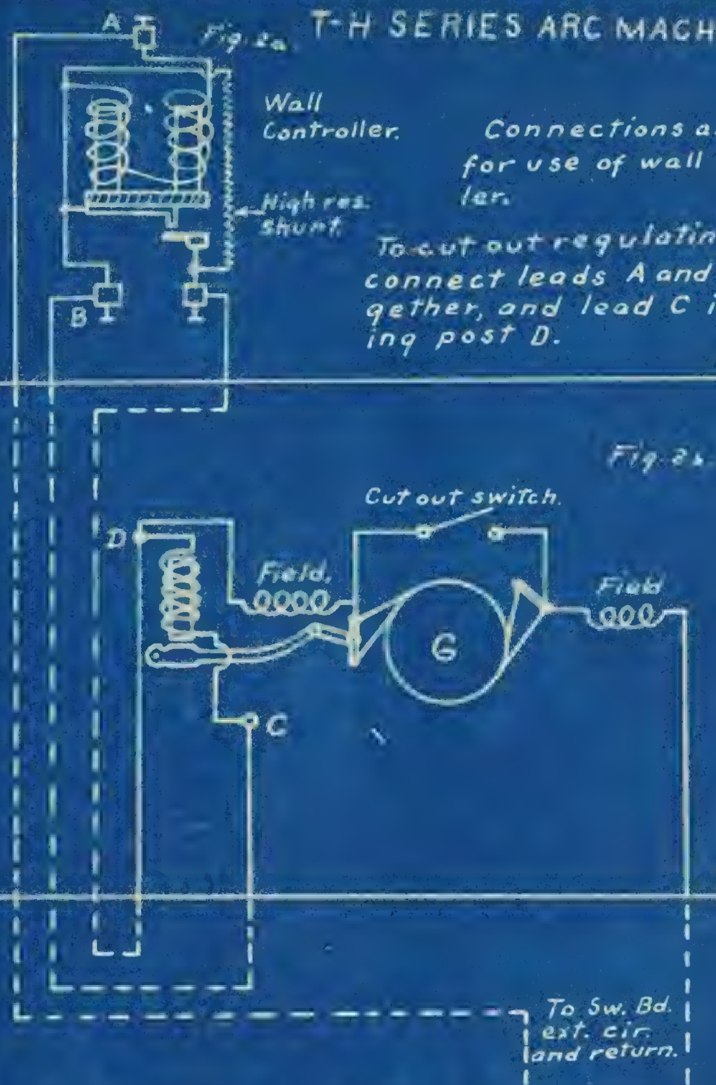


Connections as shown for use of wall controller.

To cut out controller, disconnect at B and C.

Brush Machine:- Control by shunting portion of current from field coils when lower E.M.F. is required.

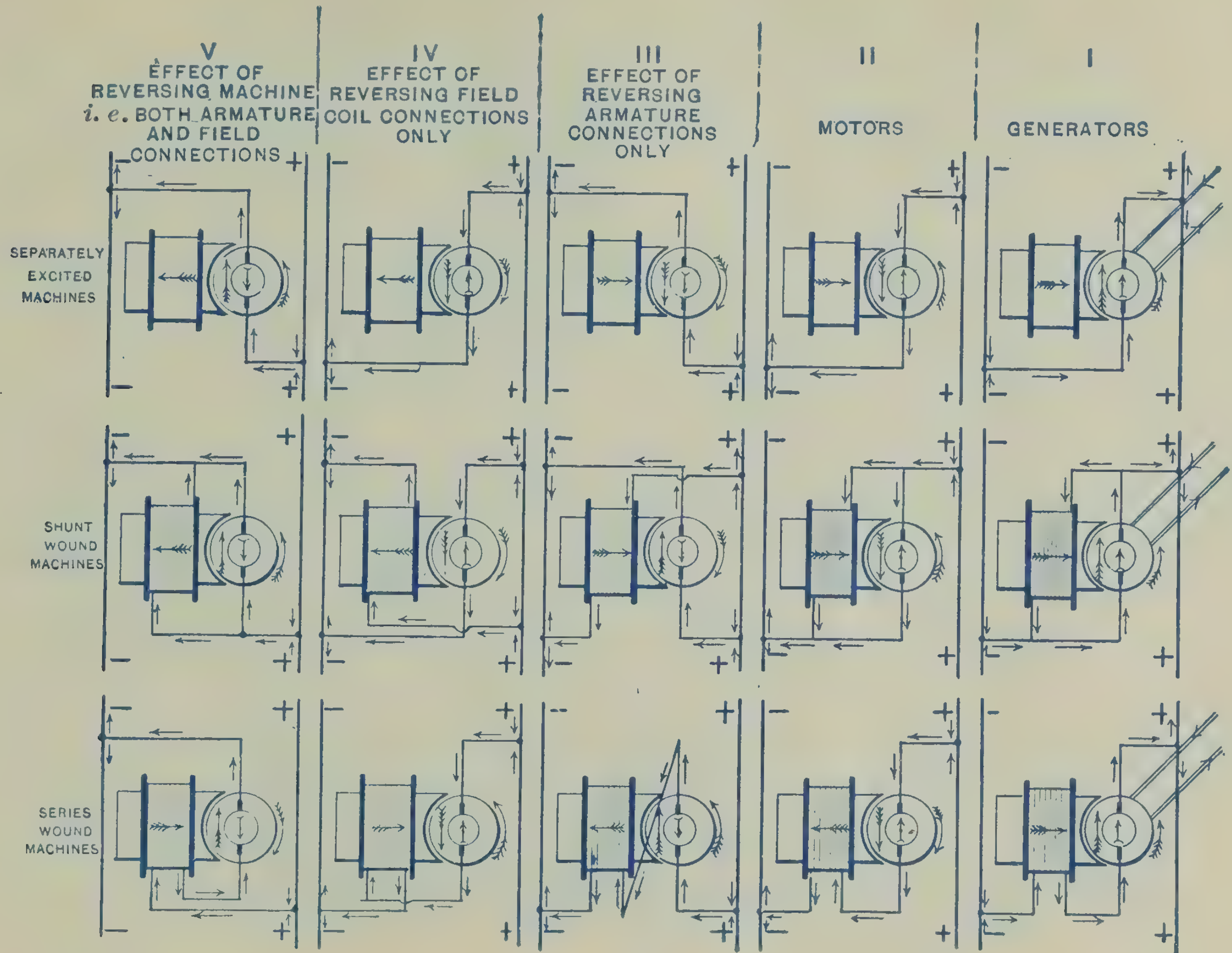
T-H SERIES ARC MACHINE.



Connections as shown for use of wall controller.

To cut out regulating device, connect leads A and B together, and lead C in binding post D.

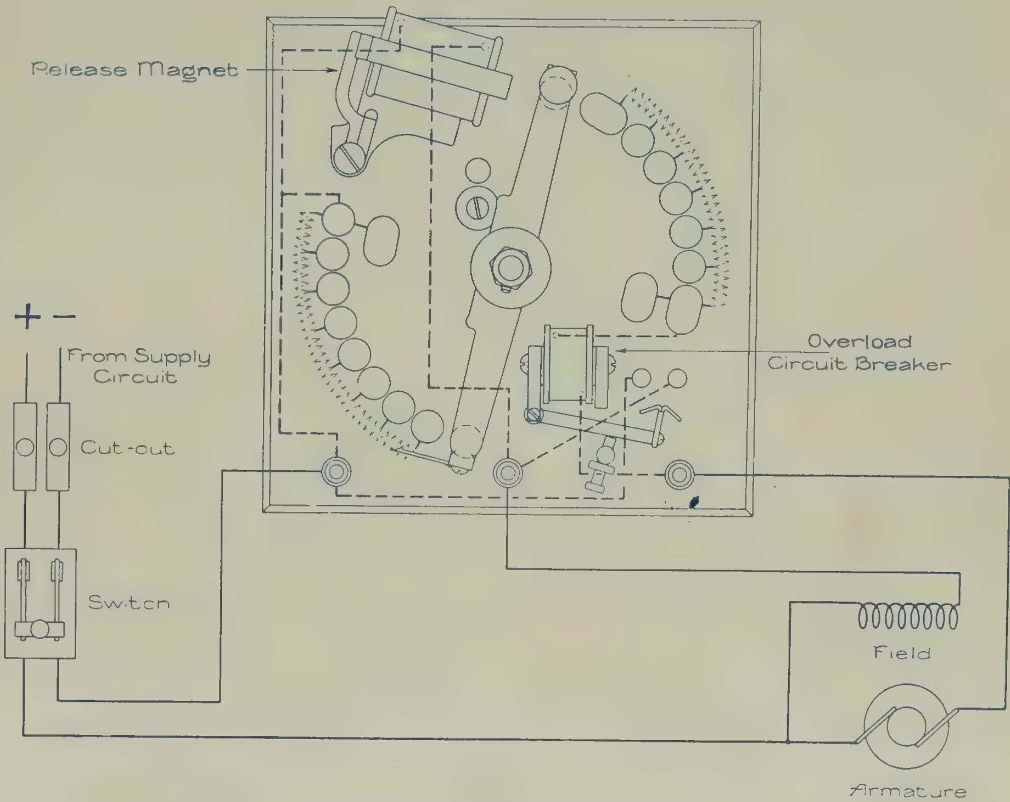
T-H Machine:- Control by shifting points of commutation of two brushes forming a pair, respectively on each side.



—DIAGRAM INDICATING DIRECTIONS OF ROTATION OF MOTORS.

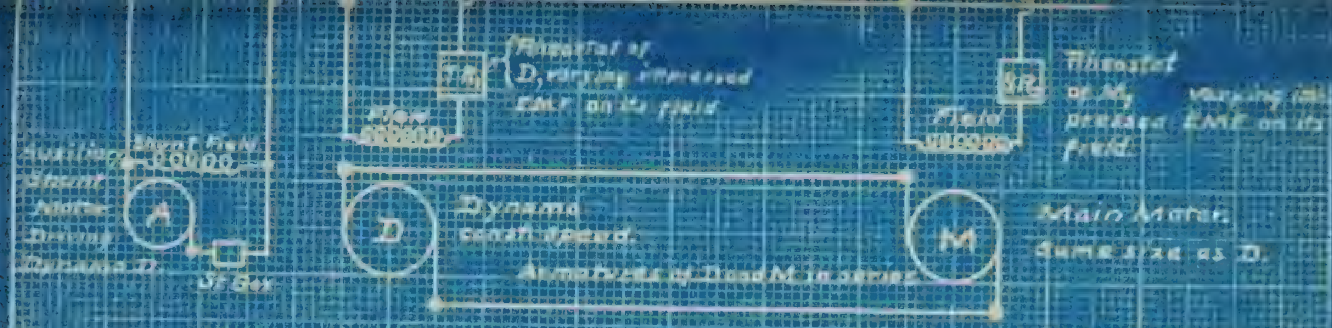
Houston and Kennelly's "Electro-Dynamic Machinery."

CONNECTIONS OF STARTING RHEOSTAT FOR SHUNT WOUND MOTORS
WITH AUTOMATIC RELEASE IN FIELD CIRCUIT OF MOTOR
AND OVERLOAD CIRCUIT BREAKER

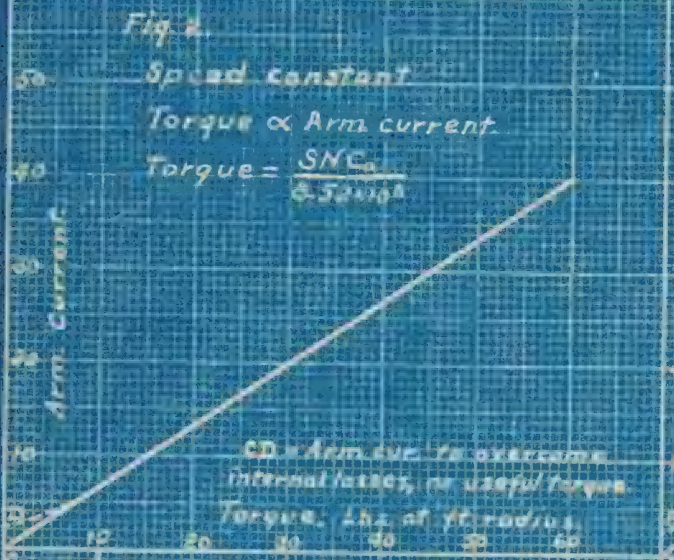


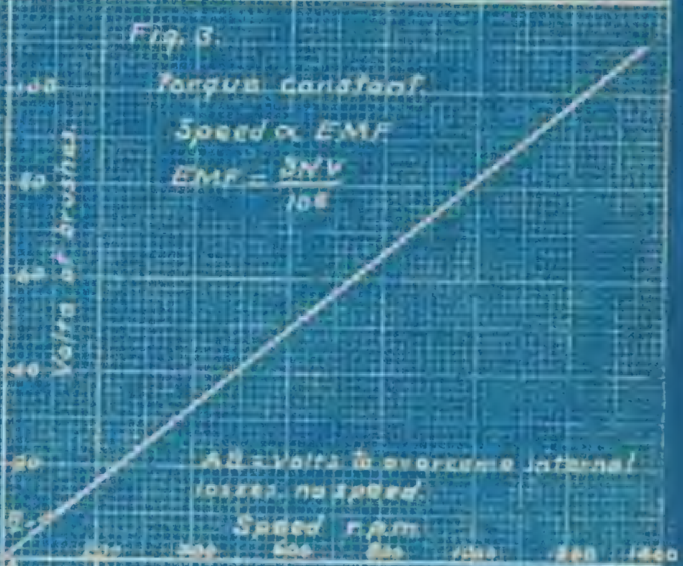
Details of Release Magnet

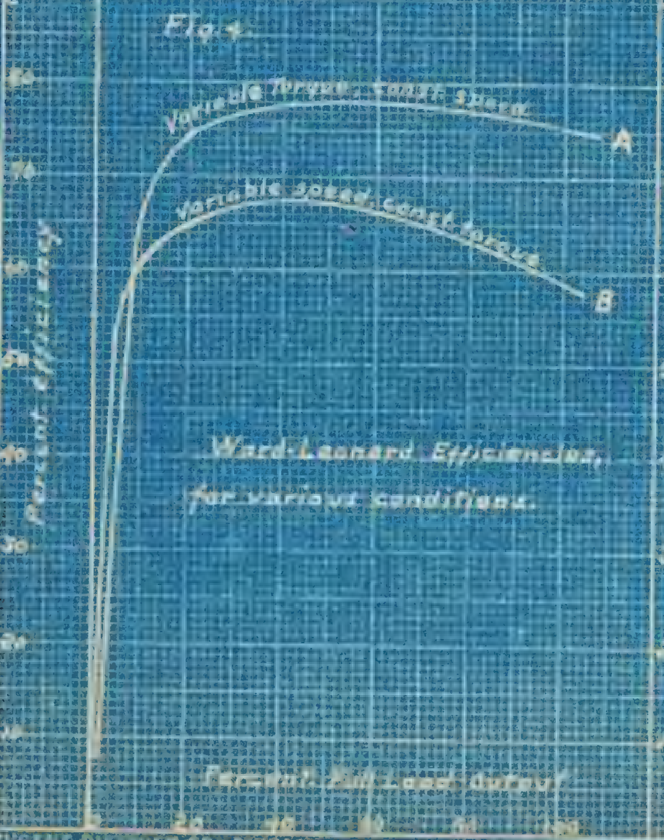
General Electric Co.

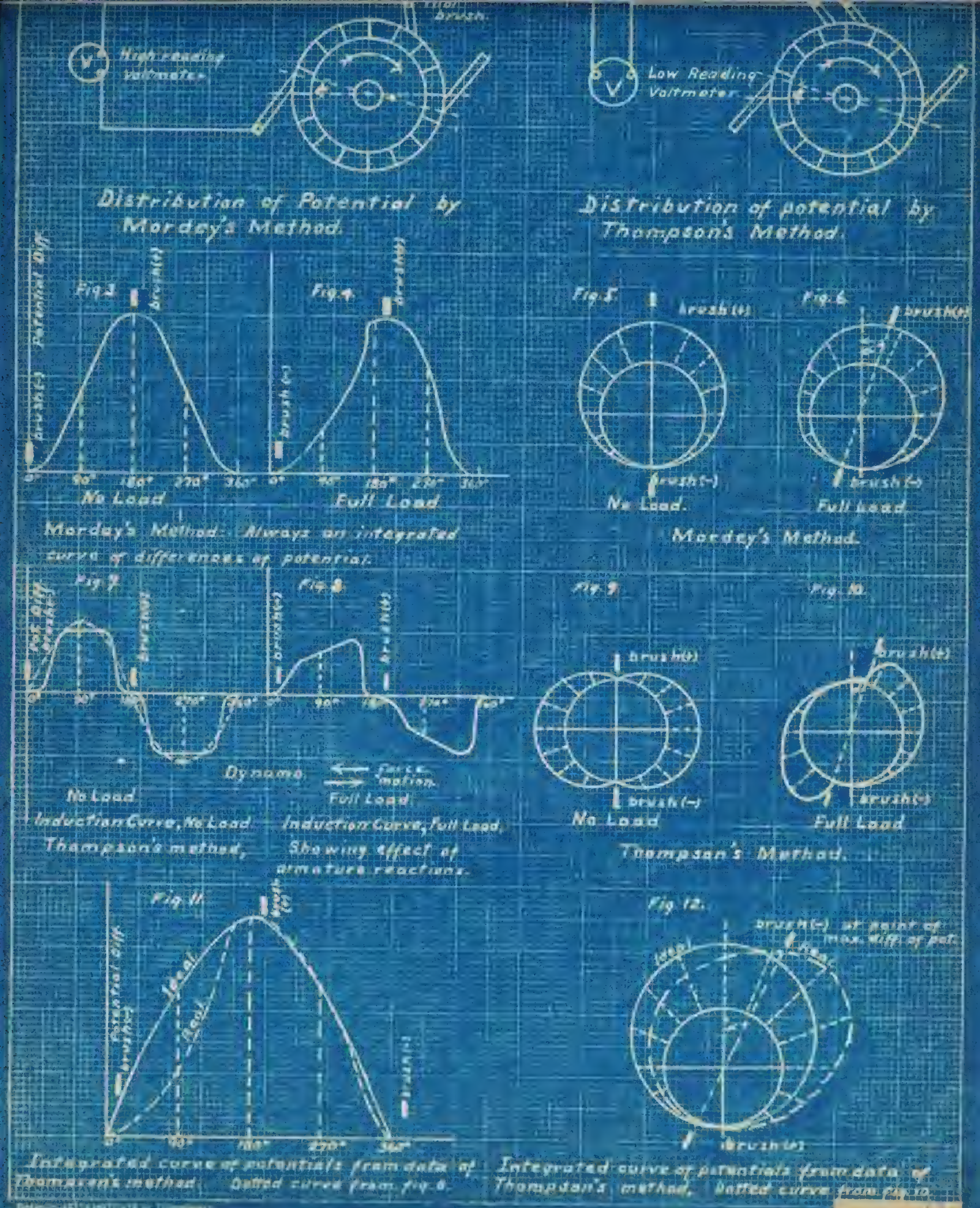


Connections for operating Ward-Leonard System of Motor Control.



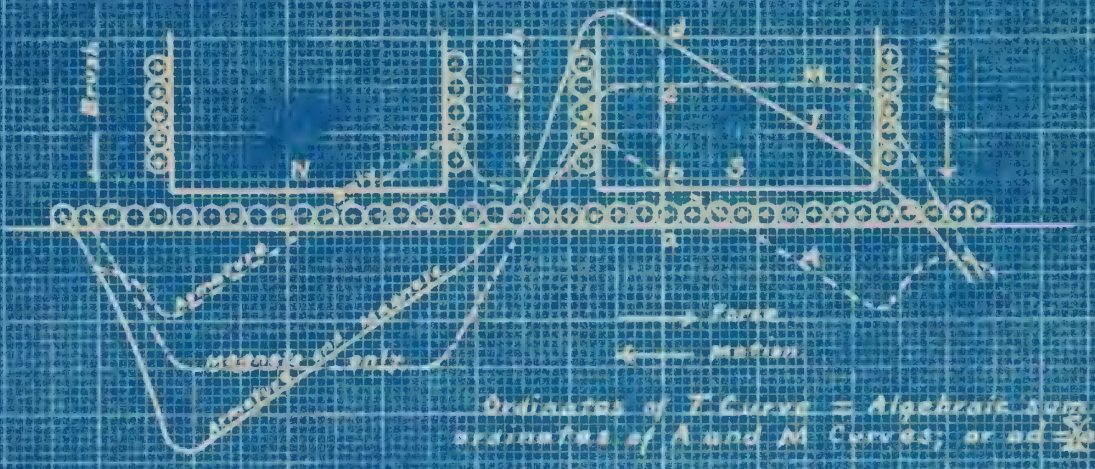





brush.
High reading Voltmeter.
Low Reading Voltmeter
Distribution of Potential by Morday's Method.
Distribution of potential by Thompson's Method.
Fig. 3
Fig. 4
Potential Diff.
brush (+)
brush (–)
0° 90° 180° 270° 360°
No Load
Full Load
Fig. 5
Fig. 6
brush (+)
brush (–)
No Load.
Full Load
Morday's Method.
Morday's Method: Always an integrated curve of differences of potential.
Fig. 7
Fig. 8
Pot. Diff.
Dynamo.
force. motion.
No Load
Full Load.
Induction Curve, No Load. Thompson's method,
Induction Curve, Full Load. Showing effect of armature reactions.
Fig. 9
Fig. 10
No Load
Full Load
Thompson's Method.
Fig. 11
Ideal
Real
Fig. 12.
brush (–) at point of max. diff. of pot.
Integrated curve of potentials from data of Thompson's method. Dotted curve from fig. 8.
Integrated curve of potentials from data of Thompson's method. Dotted curve from fig. 10.

MAGNETIZATION CURVES
GENERATOR.

Fig. 3.



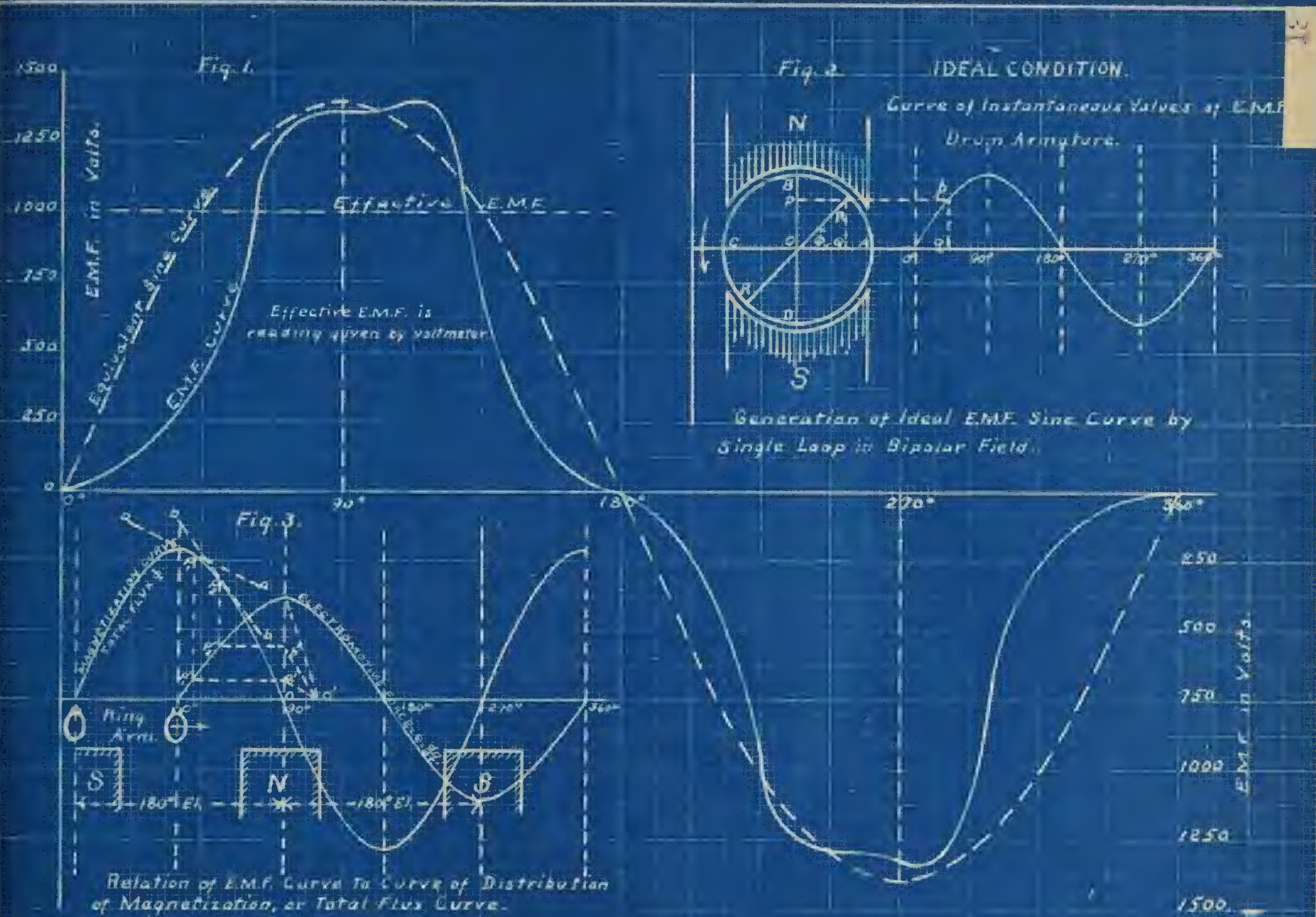
Ordinates of T Curve = Algebraic sum of ordinates of A and M Curves; or $ad = \Sigma(ab + ac)$

Ideal Curves of Induction, showing effect of Armature Reactions.

MAGNETIZATION CURVES
MOTOR.

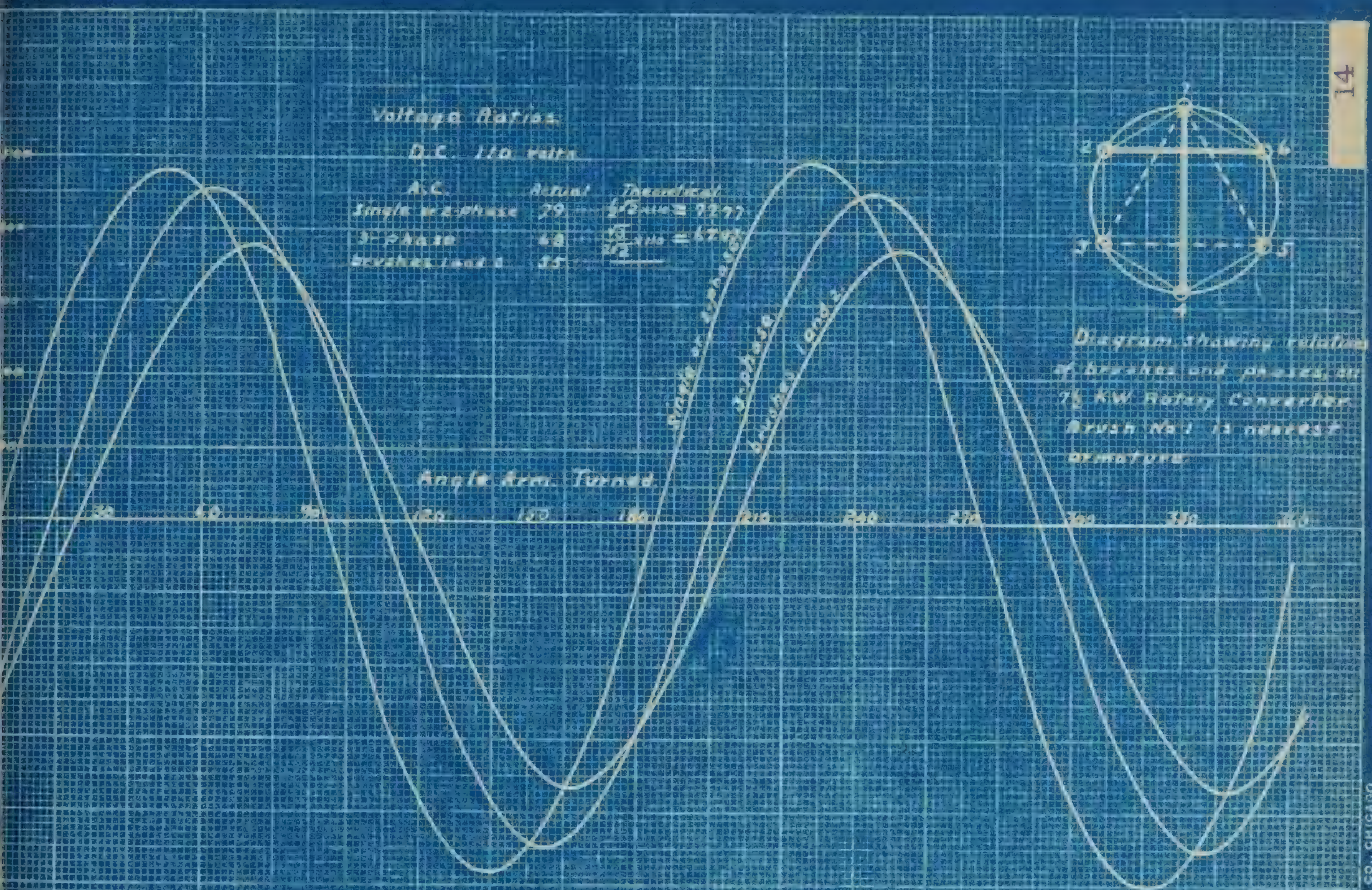
Fig. 4.

$ad = \Sigma(ac - ab)$

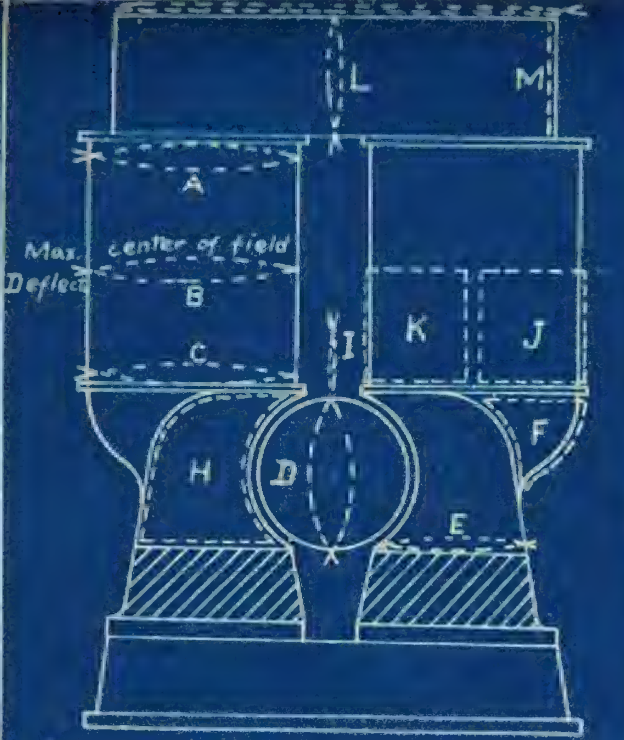


Electromotive Force Curve of a Single-phase, 1000 volt, 125 cycle, 35 K.W. Alternator.

14



Magnetization Curves of 7½ K.W. Rotary Converter.
Exciting current 0.5 amp.



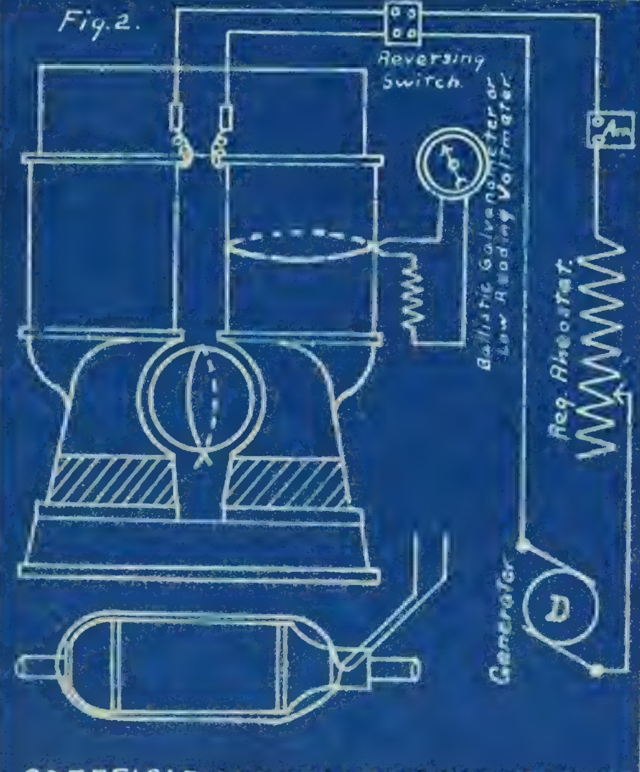
DISTRIBUTION OF WASTE FLUX.

Arrangement of coils for determination in bipolar type of dynamo.

Distribution of Waste Flux in Bipolar Dynamo

Position of Coil	Designation	Turns in coil	Mean of 5 deflect.	Deflect. per turn	Percentage of max.
Yoke end of fld coil	A				
Mid of field coil	B				
Pole end of fld coil	C				
Armature	D				
Base of pole-piece	E				
½ back of pole-piece	F				
Each side of "	H				
Across upper pole pts	I				
Outside ½ of lower ½ coil	J				
Inside ½ "	K				
Mid of yoke	L				
End of yoke	M				
Top of yoke	N				

Fig. 2.



COEFFICIENT OF MAGNETIC LEAKAGE

Connections of apparatus for determination in bipolar type of dynamo.

With Ballistic Galvanometer.

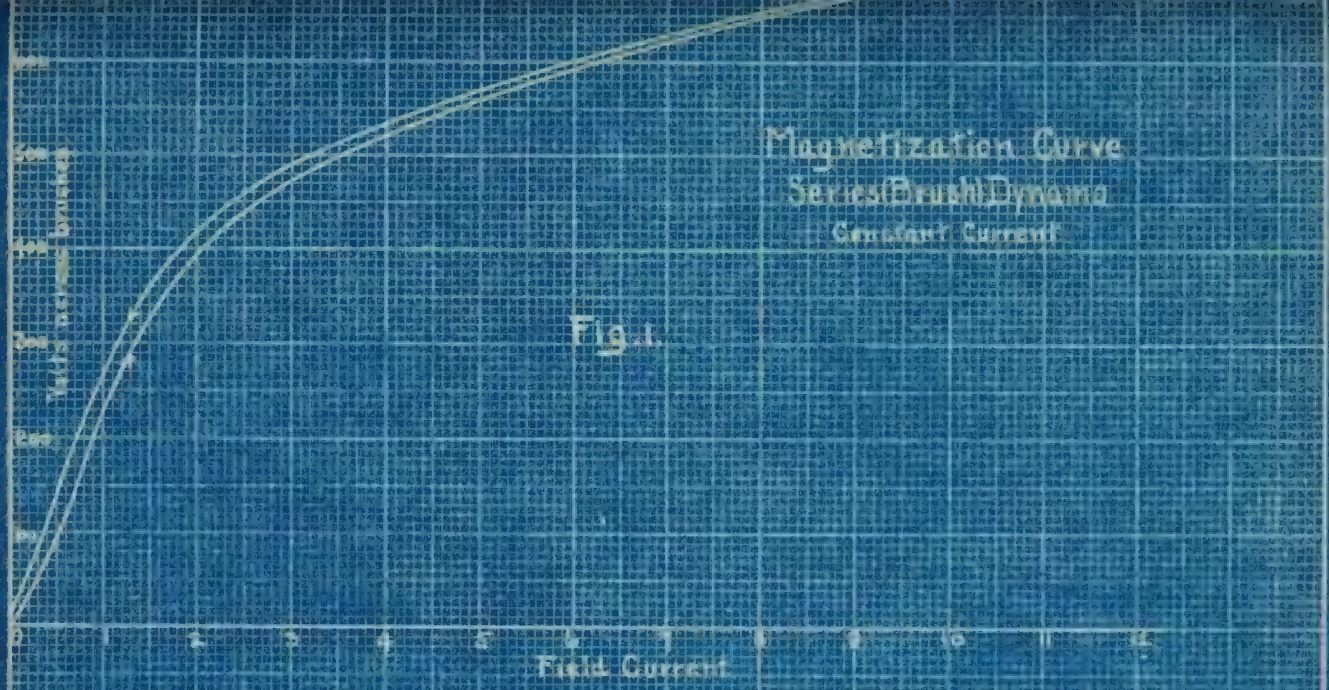
Field			Armature		
Make	Break	Diff.	Make	Break	Diff.
3.2	12.0	8.8	4.5	10.2	5.7

$$v = \text{ratio of means} = \frac{8.8}{5.7} = 1.54$$

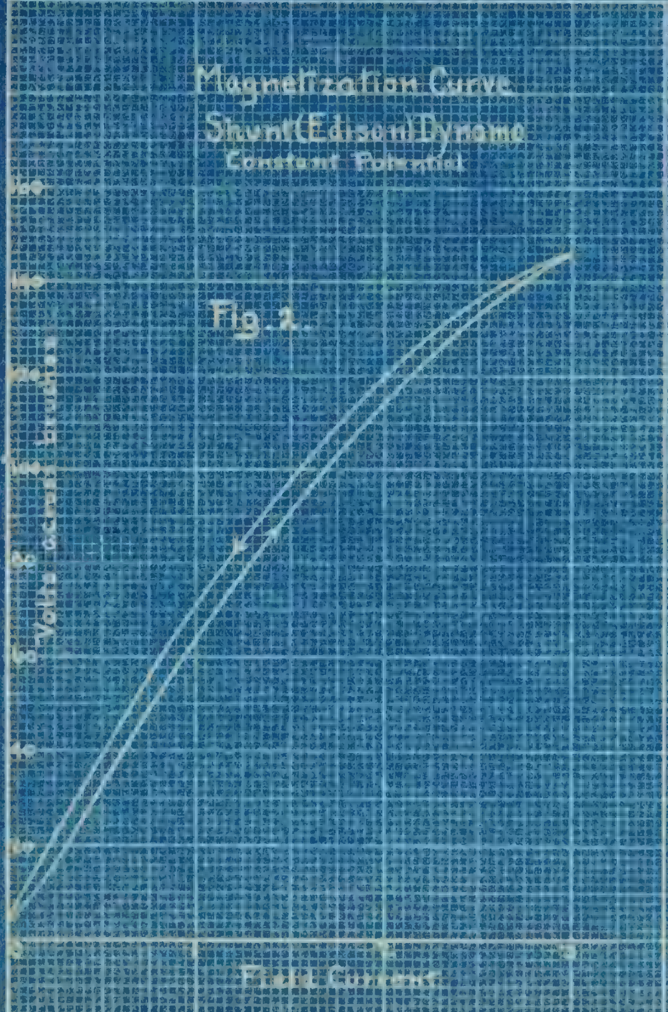
With Voltmeter.

Field			Armature		
Make	Break	Diff.	Make	Break	Diff.
1.2	6.4	5.2	1.0	4.4	3.4

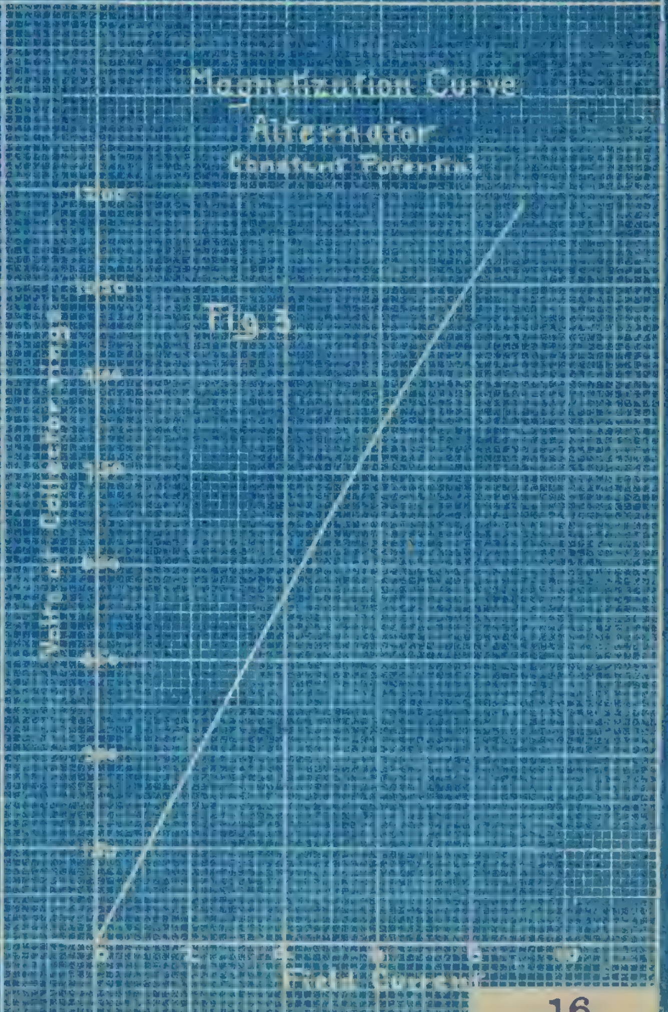
$$v = \text{ratio of means} = \frac{5.2}{3.4} = 1.52+$$



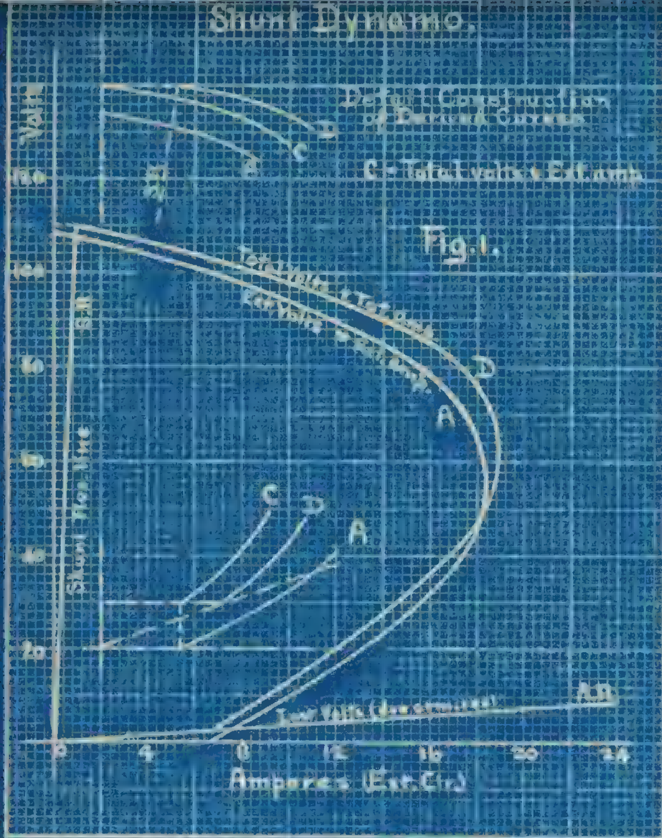
Magnetization Curve
Series(Brush)Dynamo
Constant Current
Fig.1.
Volts across brushes
Field Current

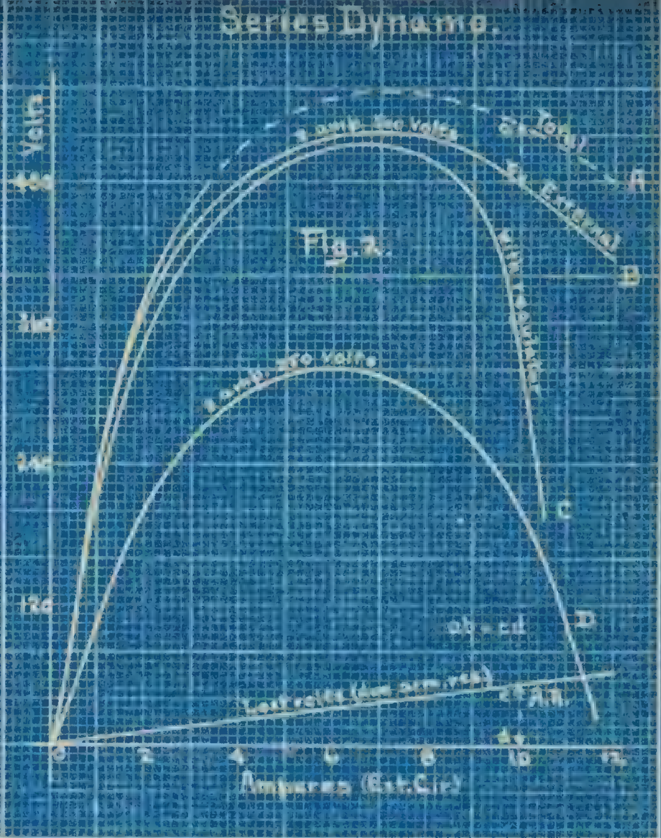


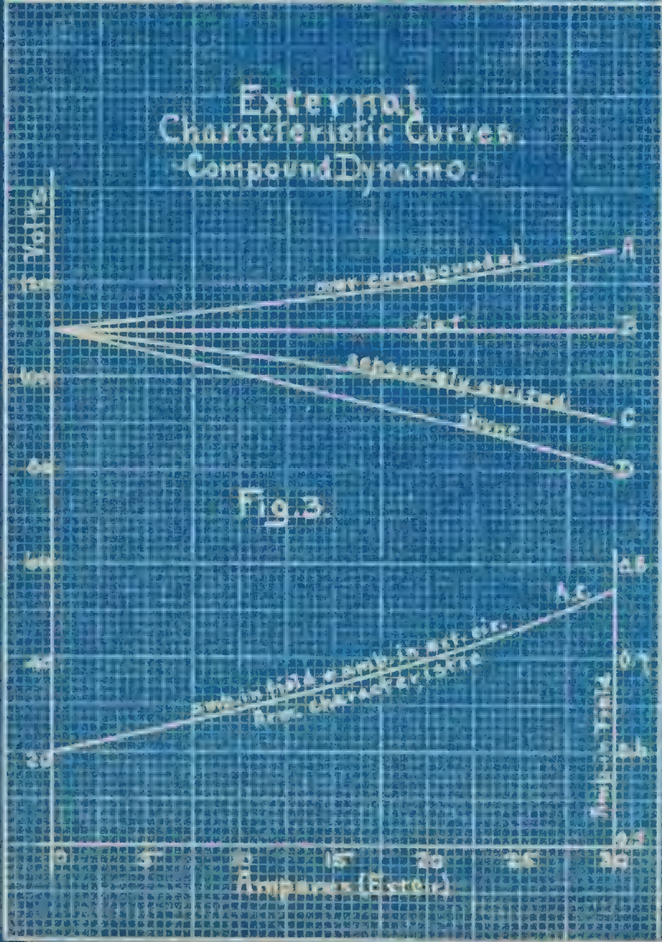
Magnetization Curve
Shunt(Edison)Dynamo
Constant Potential
Fig.2.
Volts across brushes
Field Current

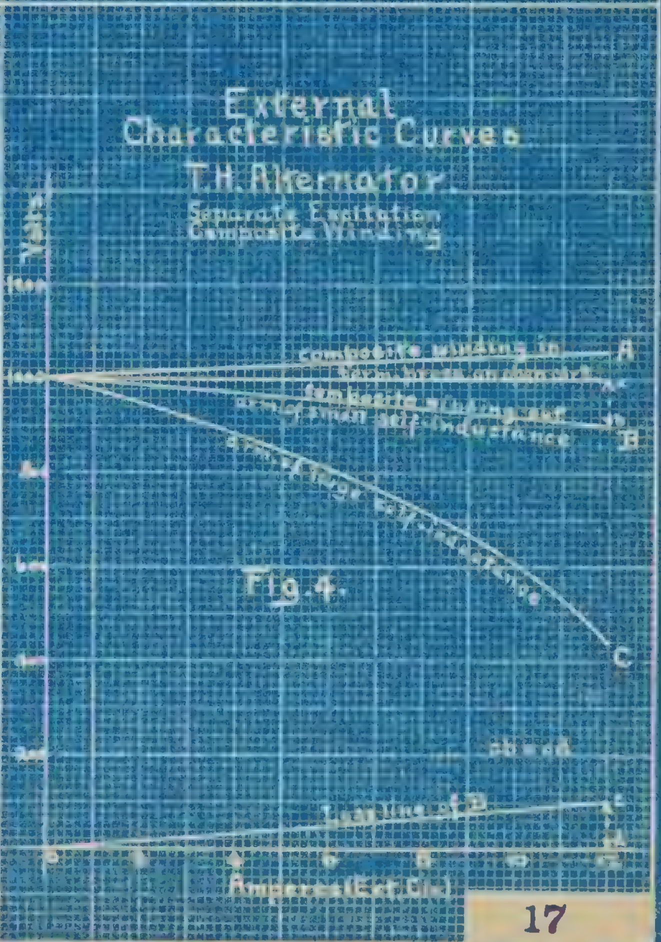


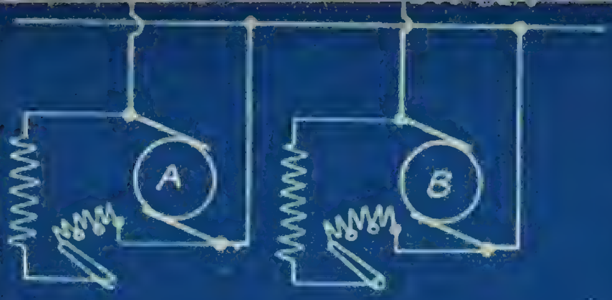
Magnetization Curve
Alternator
Constant Potential
Fig.3.
Volts at Collector rings
Field Current


Shunt Dynamo.
Detail Construction of Derived Curves.
C = Total volts & Ext. amp.
Fig. 1.
Total volts & Tot. amp.
Ext. volts & Ext. amp.
Shunt Flux line
Lost volts
Amperes (Ext. Cir.)
Volts

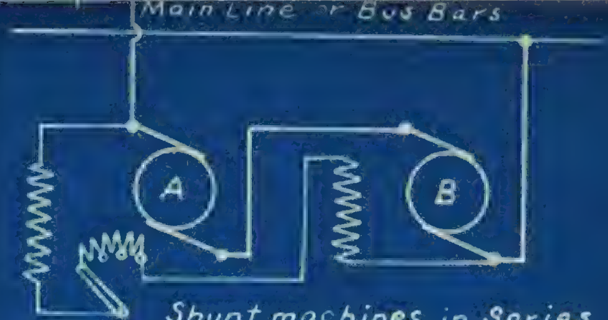

Series Dynamo.
Fig. 2.
Total
Ext. amp.
Volts
ab = cd
Lost volts
Amperes (Ext. Cir.)


External Characteristic Curves.
Compound Dynamo.
Volts
over-compounded
flat
separately excited
shunt
Fig. 3.
Armature Field
Amperes (Ext. Cir.)


External Characteristic Curves.
T. H. Alternator.
Separate Excitation
Composite Winding
Volts
composite winding in
composite winding and
small self inductance
large self inductance
Fig. 4.
ab = cd
Loss line
Amperes (Ext. Cir.)

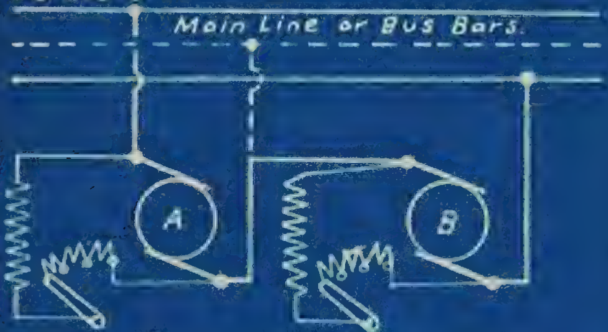


Shunt machines in Parallel.



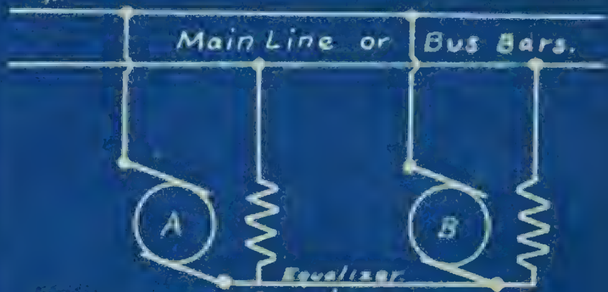
Shunt machines in Series.
(a) Fields in series.

2b. and 3.



Shunt machines in Series.
(b) Fields independent.
Dotted connections for 3-wire system.

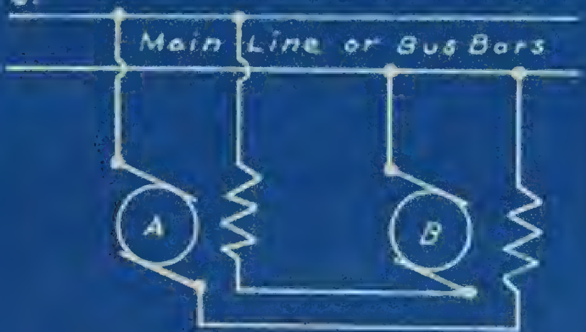
4.



Equalizer divides load proportionately between the two machines.

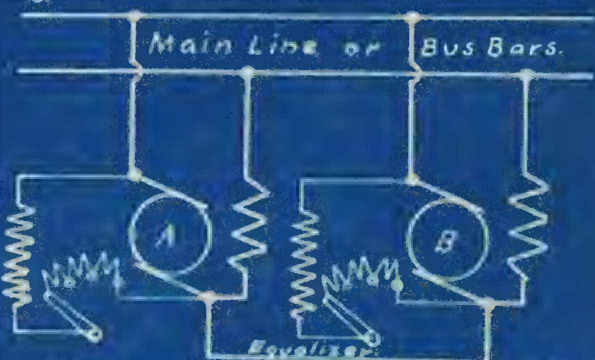
Series machines in Parallel.
With equalizer.

5.



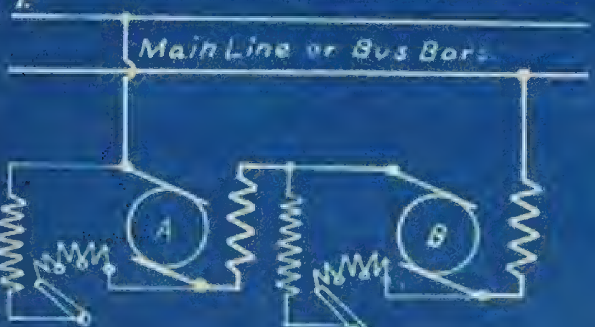
Series machines in Parallel.
Mutual Excitation.

6.



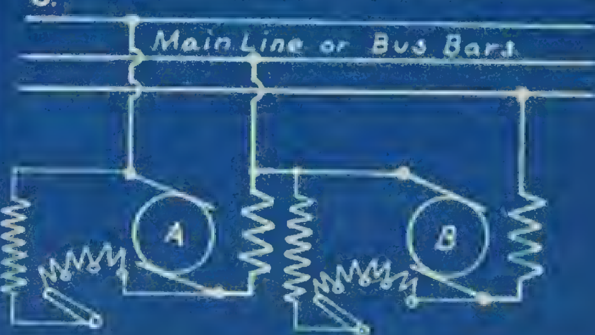
Compound machines in Parallel.

7.



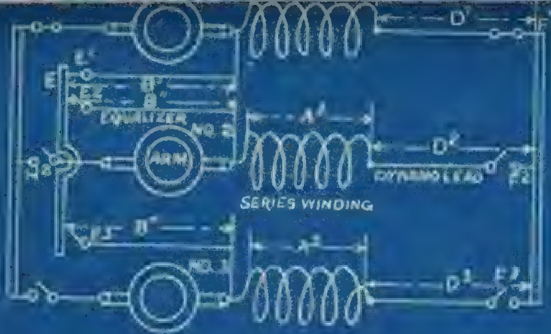
Compound machines in Series.
Two-wire system.

8.



Compound machines in Series.
Three-wire system.

DIAGRAMS FOR COUPLING D.C. DYNAMOS AND MOTORS IN SERIES AND IN PARALLEL.



EQUALIZER AT SWITCH BOARD

EQUALIZER AT DYNAMO

THE CIRCUITS THAT AFFECT THE MUTUAL COMPOUNDING OF DYNAMOS WORKING IN MULTIPLE ARC,ARE THE SERIES WINDING A'; EQUALIZERS, B', AND DYNAMO LEADS, D',FIG.1,SHEET 3. TO OPERATE ANY COMPOUND DYNAMOS IN MULTIPLE, SO THAT THEY WILL CARRY VARYING LOADS IN PROPORTION TO THEIR OUTPUTS, THE FOLLOWING RULES MUST BE OBSERVED:THAT THE RESISTANCE A',B' AND D' CONSTITUTE THOSE RESISTANCES WHICH ARE INVOLVED IN PROPERLY EQUALIZING THE DYNAMOS,AND THAT THE CONDUCTIVITY OF THE EQUALIZER CIRCUITS FOR EACH DYNAMO MUST BEAR THE SAME RATIO TO THE CONDUCTIVITY OF ALL EQUALIZING CIRCUITS IN MULTIPLE,AS THE OUTPUT OF EACH DYNAMO BEARS TO THE TOTAL OUTPUT OF ALL DYNAMOS.

FIRST,CONSIDER EQUALIZING DYNAMOS OF THE SAME DESIGN AND OUTPUT; THE USUAL METHOD OF CONNECTING IS SHOWN IN FIG.1. TO MAKE THESE DYNAMOS WORK PROPERLY TOGETHER,IT IS NECESSARY THAT THE RESISTANCE BETWEEN EQUALIZER BUS,E,AND BUS,F,BE THE SAME FOR ALL DYNAMOS, AND THAT BUS E SHOULD NOT HAVE ANY APPRECIABLE RESISTANCE, OR THE EQUALIZERS MAY BE DIRECTLY TIED TOGETHER, AS IN FIG.2. IF DYNAMO NO.1 IS ON THE BUS, AND IT IS REQUIRED TO THROW DYNAMO NO.2 IN PARALLEL WITH IT,EQUALIZER SWITCH,E^2,IS THROWN;THIS HAS NO EFFECT UNTIL SWITCH,F^2,IS THROWN;THEN THE CURRENT FLOWS THROUGH THE SERIES COIL OF NO.2,AND IS DIVERTED FROM THE SERIES WINDING OF THE OPERATING DYNAMO; THE AMOUNT OF CURRENT THUS DIVERTED DEPENDS ON THE RATIO OF THE TWO PARALLEL CIRCUITS.

IS THROWN IN, AND THE CURRENT GRADUALLY FADES OUT OF THE EQUALIZER CONNECTION, AS DYNAMO NO.2 TAKES ITS PROPORTION OF THE LOAD, THE EQUALIZER CONNECTION HAS THE FUNCTION OF MAINTAINING THE SAME VOLTAGE AT THE TERMINALS OF THE TWO MACHINES, AND THERE WILL BE NO TENDENCY TO CROSS-COMPOUND.

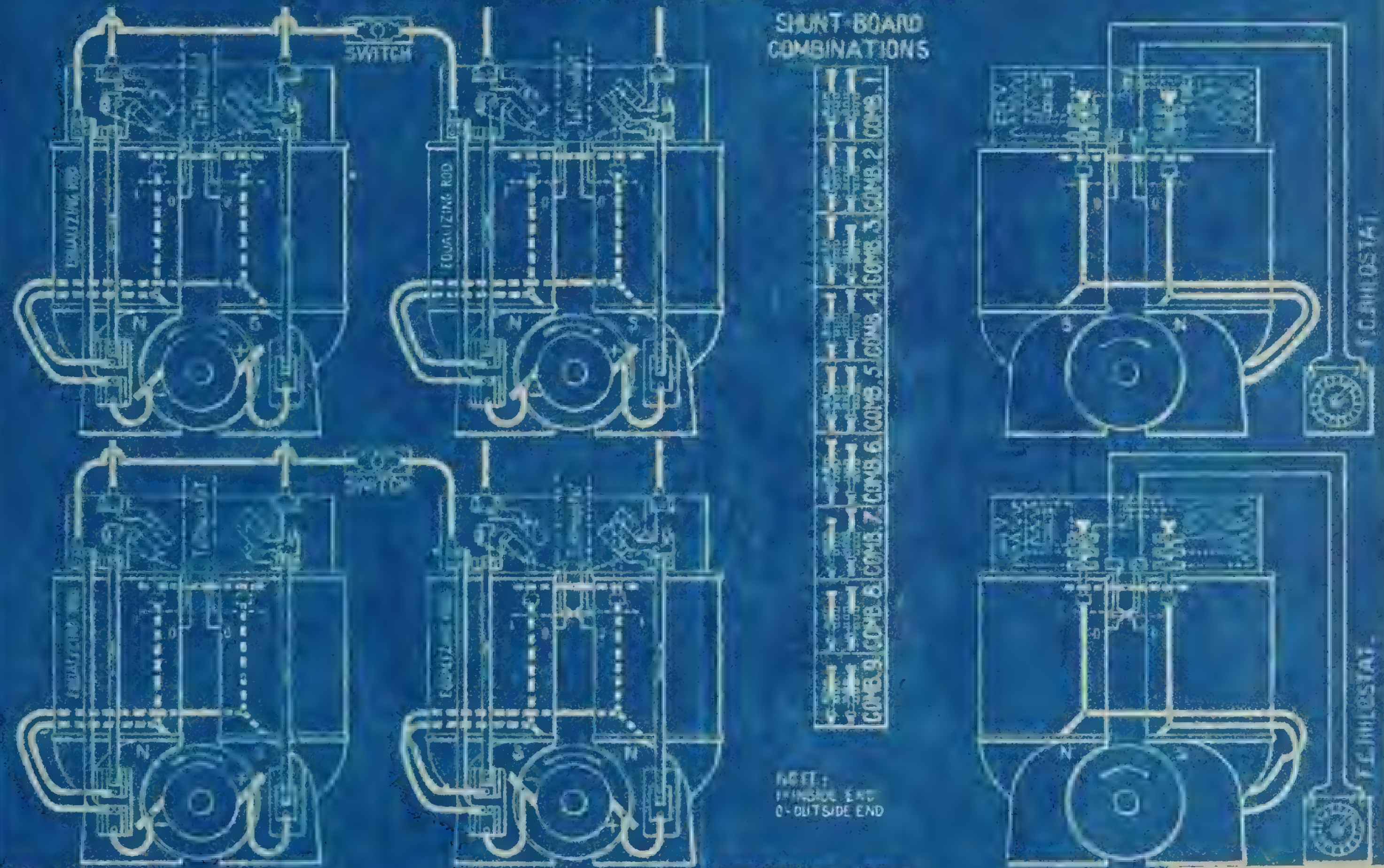
WHERE SIMILAR DYNAMOS ARE LOCATED AT DIFFERENT DISTANCES FROM THE SWITCHBOARD,THEIR EQUALIZING CONNECTIONS MUST BE ALL EQUAL IN RESISTANCE TO THE GENERATOR WHICH HAS THE LONGEST LEADS,IF THE SAME CURRENT DENSITY HAS BEEN FIGURED ON ALL THE LEADS. IN EQUALIZING DYNAMOS OF DIFFERENT DESIGNS AND OUTPUTS,THE SAME RELATION OF EQUALIZING CIRCUITS MUST EXIST BETWEEN THE DIFFERENT DYNAMOS,AS IN SIMILAR DYNAMOS, EXCEPT THAT THE RESISTANCE OF THE DIFFERENT EQUALIZER CIRCUITS DECREASES AS THE OUTPUT OF THE DYNAMO INCREASES. IN OTHER WORDS,THE DROP BETWEEN THE EQUALIZER BUS-BAR AND SERIES BUS-BAR MUST BE THE SAME FOR ALL UNITS WORKING IN PARALLEL,WHERE FULLY LOADED,OR THE MAXIMUM CURRENT DELIVERED BY UNIT,MULTIPLIED BY THE RESISTANCE OF ITS EQUALIZER CIRCUIT,MUST BE EQUAL TO A CONSTANT,WHICH IS $C\ R = E$.

TWO METHODS OF CONNECTING EQUALIZERS ARE RECOMMENDED; ONE TO TAKE EQUALIZERS BACK TO THE SWITCHBOARD, AND THE OTHER TO EQUALIZE AT THE GENERATORS. THE ONLY ADVANTAGES GAINED BY THE FIRST METHOD IS THAT THE EQUALIZING CONNECTION IS UNDER THE CONTROL OF SWITCHBOARD ATTENDANT,BUT AS THE RESISTANCE OF EQUALIZER LEAD IS INCREASED ,THE MACHINES DO NOT TEND TO DIVIDE THE LOAD SO READILY BETWEEN THEMSELVES, AND ACT MORE AS INDEPENDENT MACHINES IN MULTIPLE.

CONNECTIONS FOR

EDISON BI-POLAR GENERATORS

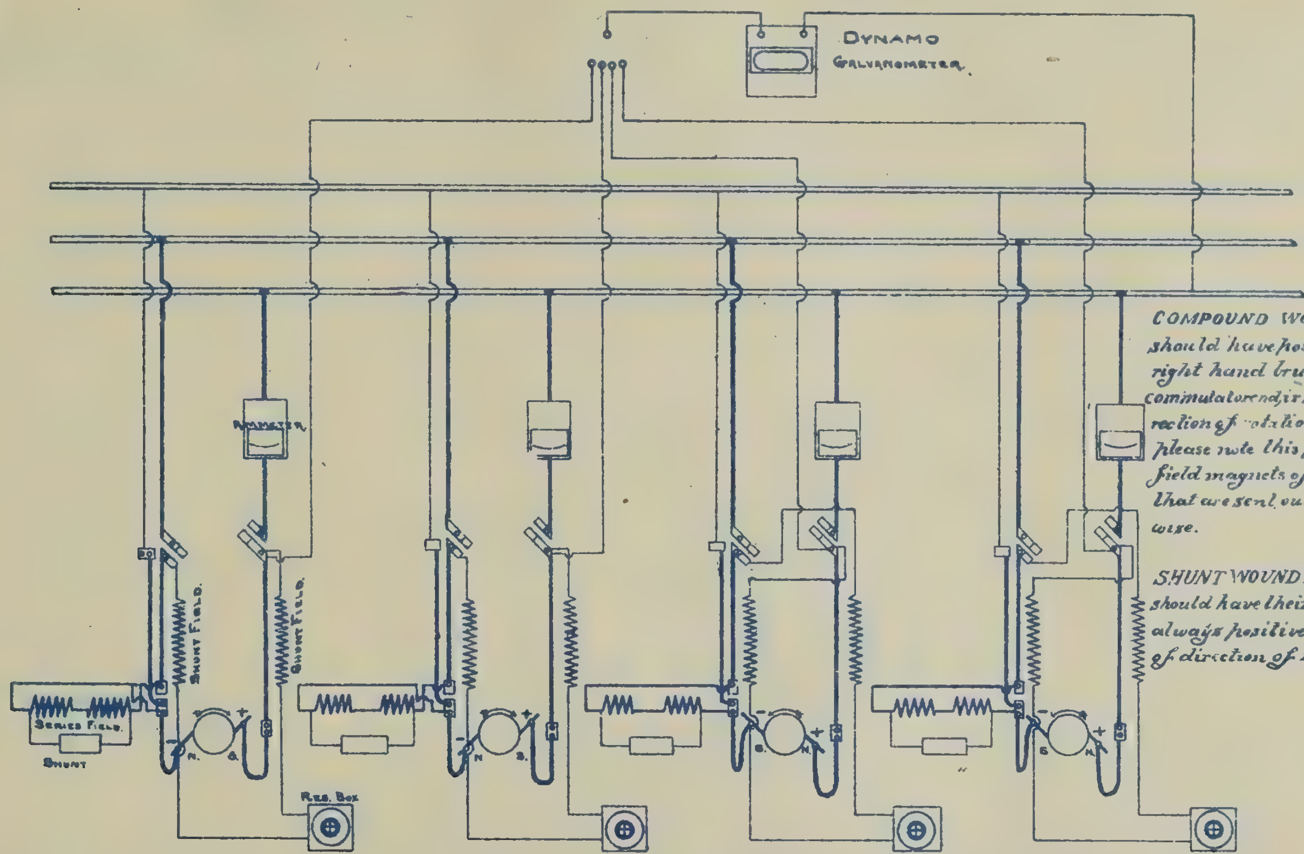
COMPOUND WOUND, IN PARALLEL.



No. 13013.

GENERAL ELECTRIC CO

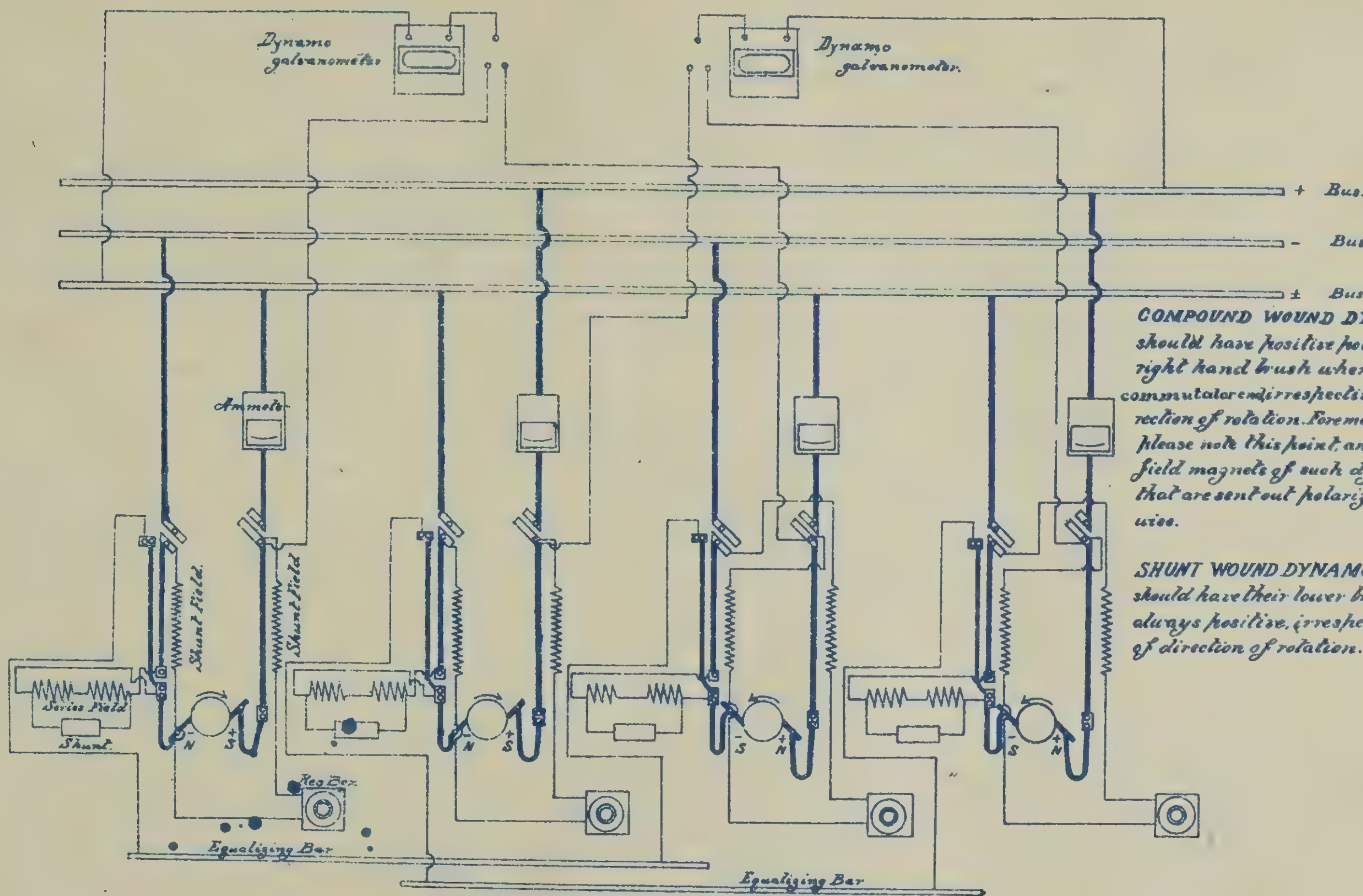
W.B.C.



COMPOUND WOUND DYNAMOS should have positive polarity on right hand brush when facing commutator end, irrespective of direction of rotation. Foremen will please note this point and recharge field magnets of such dynamos that are sent out polarized otherwise.

SHUNT WOUND DYNAMOS. should have their lower brushes always positive, irrespective of direction of rotation.

DIAGRAM OF CONNECTIONS FOR COMPOUND DYNAMOS IN MULTIPLE.
EDISON GENERAL ELECTRIC CO.



EDISON GENERAL ELECTRIC CO.

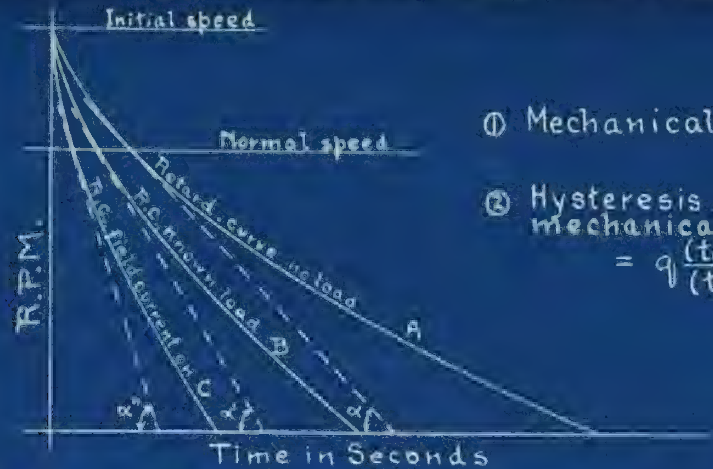
Diagram of connections for compound dynamos on three wire system

COMPOUND WOUND DYNAMOS should have positive polarity on right hand brush when facing commutator irrespective of direction of rotation. Foremen will please note this point, and recharge field magnets of such dynamos that are sent out polarized otherwise.

SHUNT WOUND DYNAMOS. should have their lower brushes always positive, irrespective of direction of rotation.

I. SEPARATION OF LOSSES BY SPEED OBSERVATIONS ALONE (Claude)

Fig. 1.



① Mechanical Losses $= q\dfrac{\tan\alpha}{(\tan\alpha' - \tan\alpha)}$

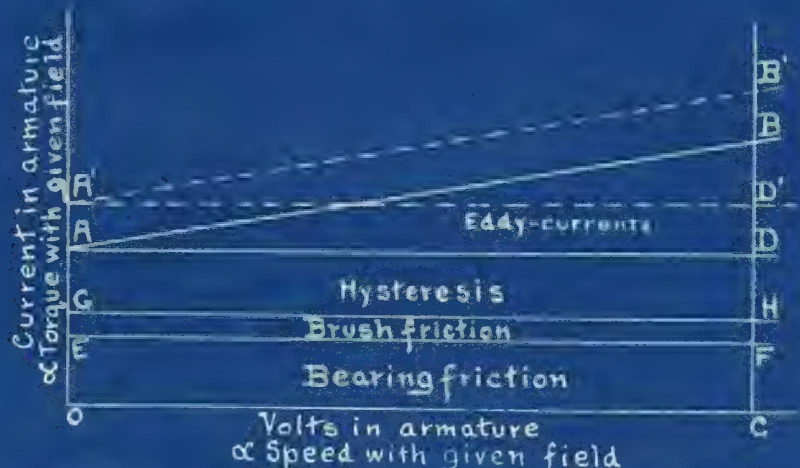
② Hysteresis, eddy-current, and mechanical losses $= q\dfrac{(\tan\alpha'' - \tan\alpha)}{(\tan\alpha' - \tan\alpha)}$

[Ref.- Sc. Abs. Vol. I, p. 99.]

Use machine as motor, run above normal speed; cut off armature and field currents; determine retardation curves for no load, and known load, (A & B) by noting instantaneous speeds with tachometer. Then with field current on, no brake, determine retardation curve C. Let q = known power absorbed by brake at normal speed, and draw, at that point, tangents to retardation curves. Equations ① and ② give the losses.

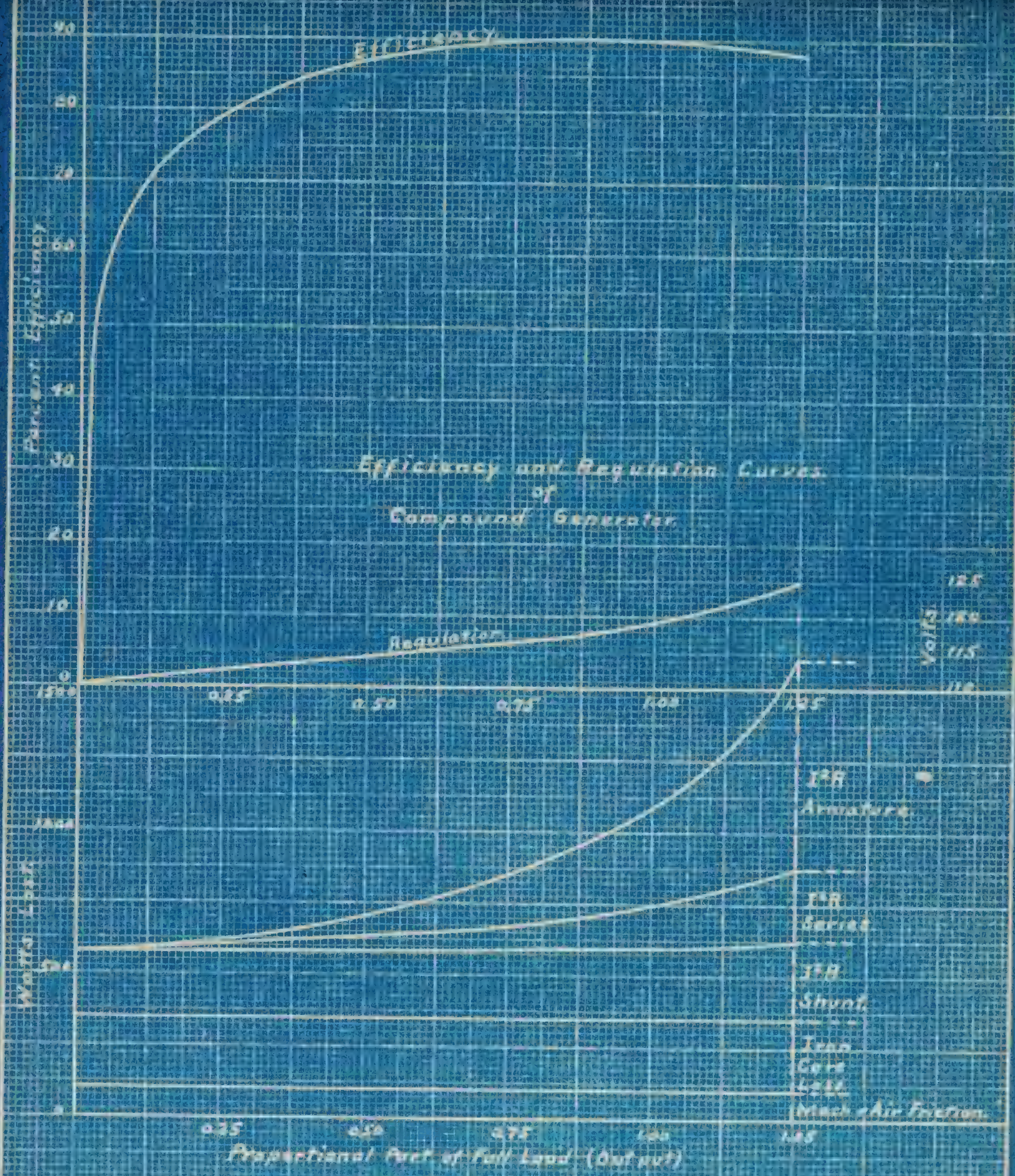
II. SEPARATION OF LOSSES BY STRAY POWER METHOD. (Kapp)

Fig. 2.



Stray power = sum of friction, eddy-current, and hysteresis losses. Eddy-current loss proportional to square of speed; friction and hysteresis losses proportional (approx) to speed.

Run armature as motor, no load, at diff. speeds using diff. volts, and measure currents required; results give st. line AB. Draw AD parallel to OC; then CD represents losses ∝ speed, and DB those ∝ square of speed. Using a diff. field strength gives A'B', increasing only the hysteretic loss.



Separation of Losses in a Compound Generator.

Machines to be of same type and size, and driven at proper speed by belt or mechanical connection.

In Hopkinson's method the losses in each machine are assumed to be the same, whether operated as dynamo or motor.

In Kapp's method the efficiencies of each machine are assumed to be the same, whether operated as dynamo or motor.

Fig. 1. HOPKINSON'S CIRCULATING (MOTOR-GENERATOR) TEST.

Motor Efficiency $= \dfrac{A_cV_c - \dfrac{A_iV_i}{2}}{A_cV_c + A_mV_i}$; Dynamo Efficiency $= \dfrac{A_cV_c - A_iV_i}{A_cV_c - \dfrac{A_iV_i}{2} + A_dV_i}$.

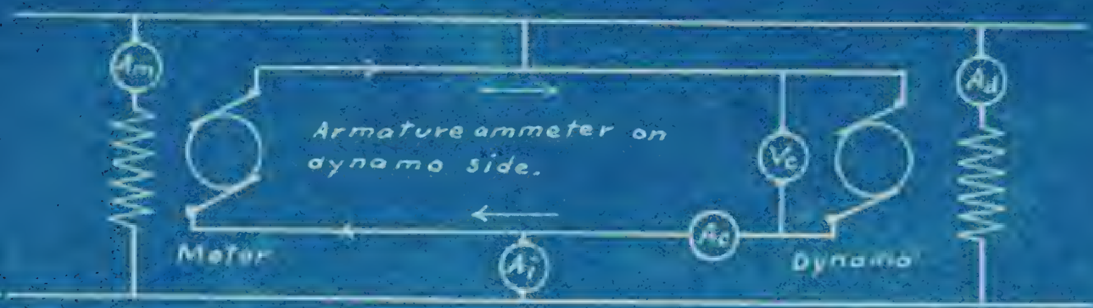


Fig. 2. HOPKINSON'S CIRCULATING (MOTOR-GENERATOR) TEST.

Motor Efficiency $= \dfrac{A_cV_c + \dfrac{A_iV_i}{2}}{A_cV_c + A_iV_i + A_mV_i}$; Dynamo Efficiency $= \dfrac{A_cV_c}{A_cV_c + \dfrac{A_iV_i}{2} + A_dV_i}$.

Fig. 3. KAPP'S METHOD OF TESTING EFFICIENCIES.

A_1 = Current when switch is to right; A_2 = Current, switch to left.

Efficiency of combination $= \dfrac{A_1}{A_2}$; Efficiency of either machine $= \sqrt{\dfrac{A_1}{A_2}}$.

ARC LAMP DROP MEASUREMENTS

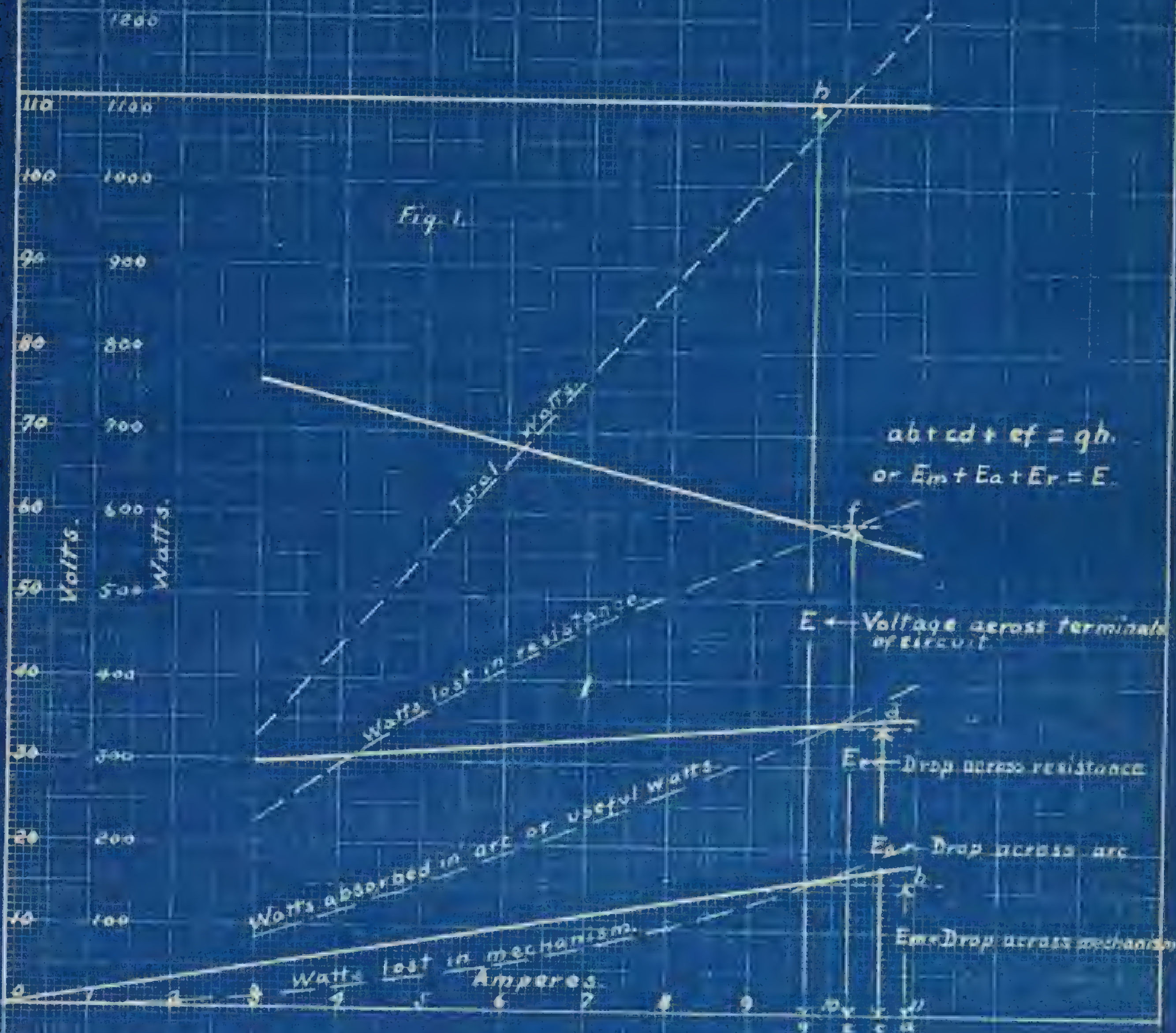
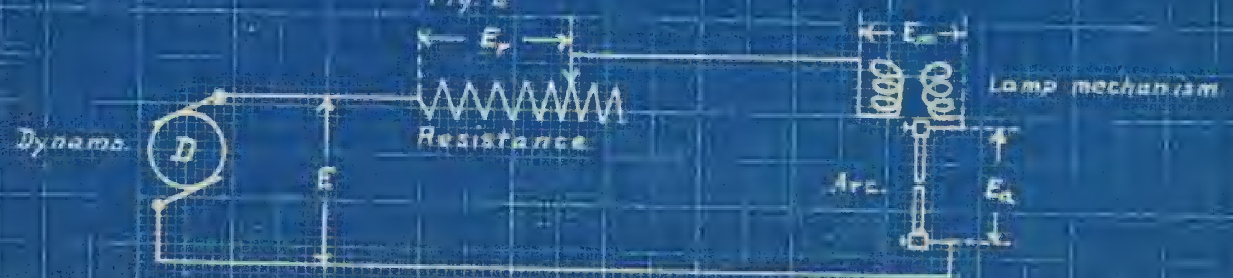
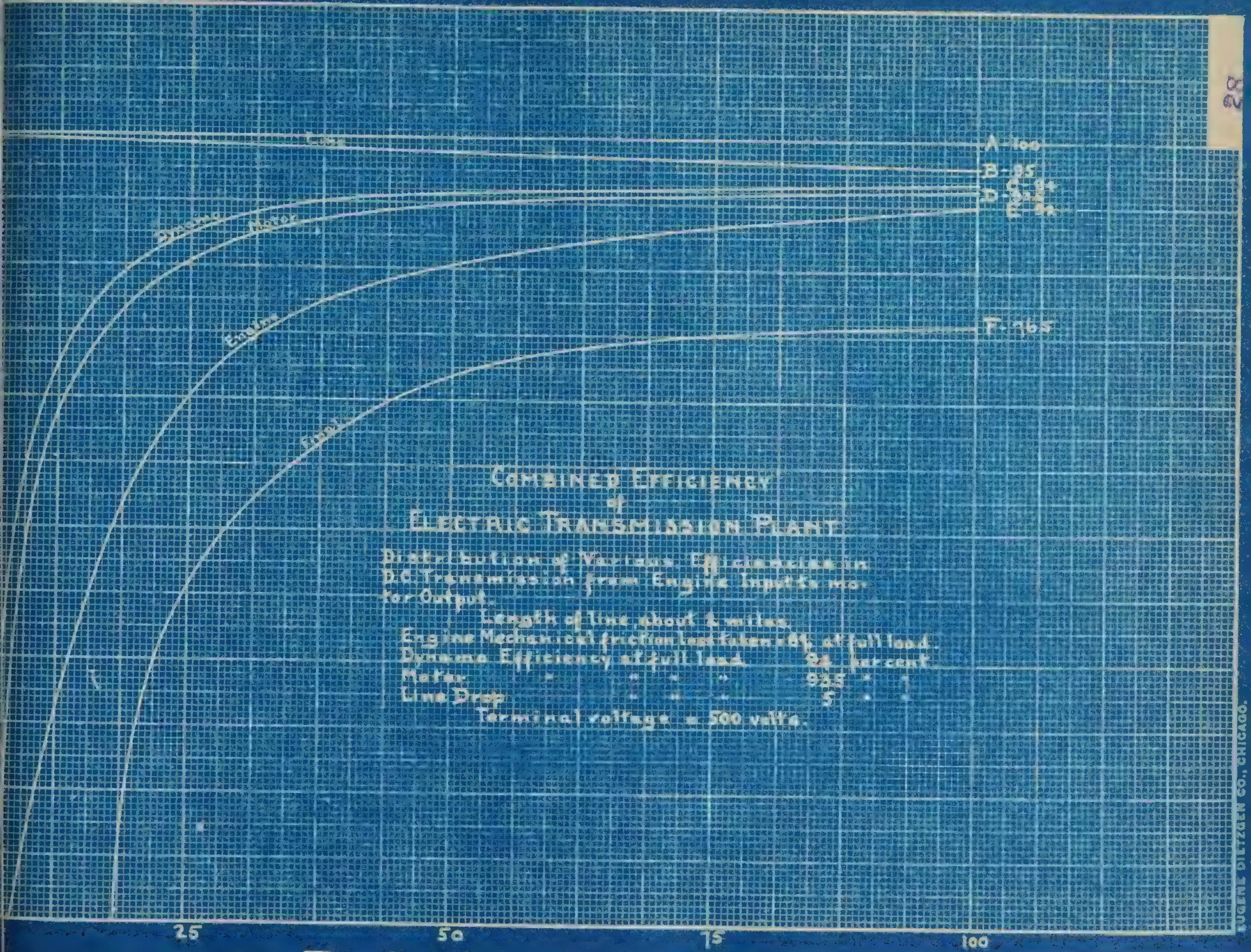


Fig. 2



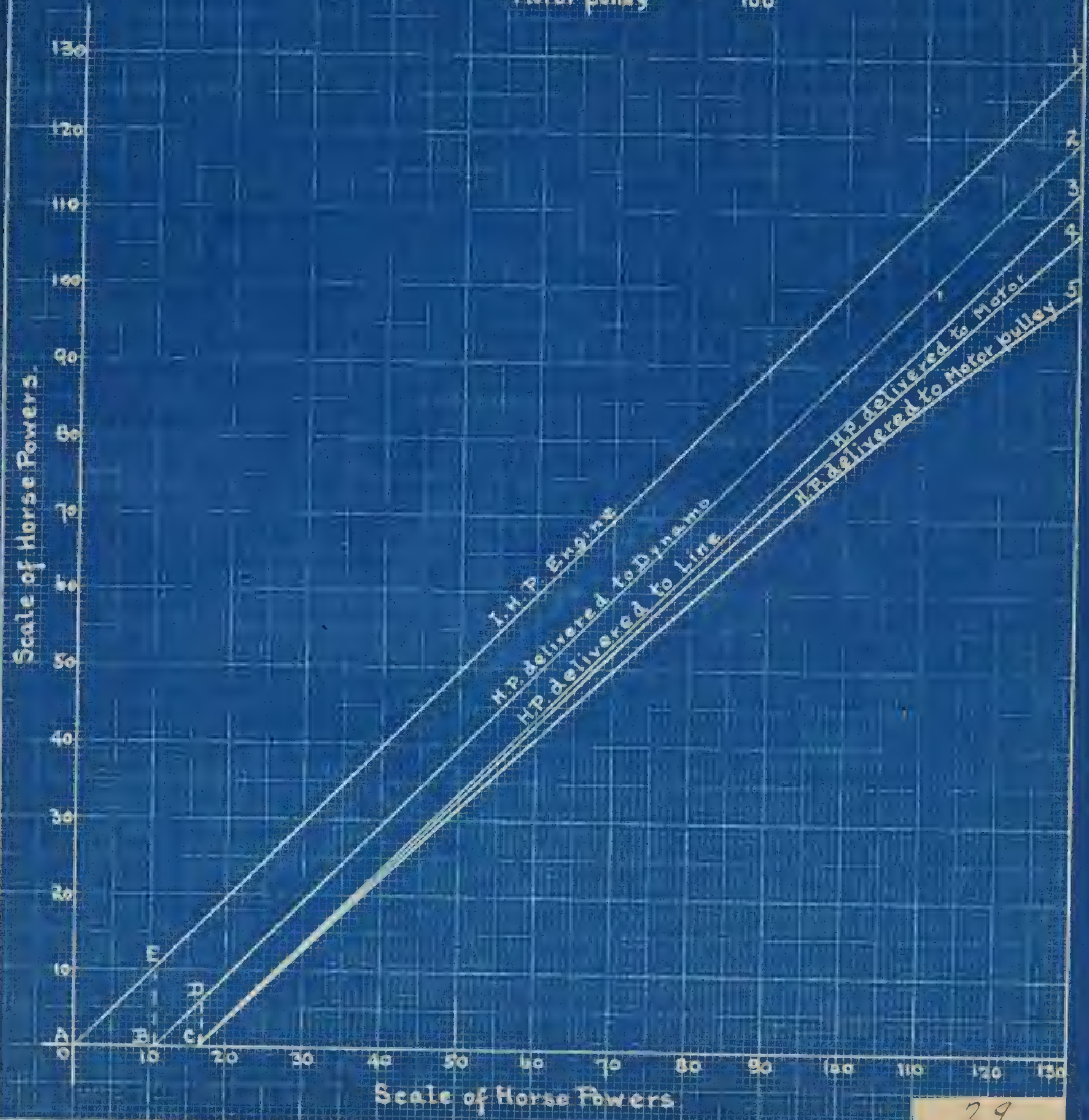


Per Cent Load (Input)

CURVES OF POWER DISTRIBUTION
of
ELECTRIC TRANSMISSION

Distribution of Power and Losses in D.C. Transmission, from Engine input (I.H.P.) to Motor output.

I.H.P. Engine, full load	130
H.P. delivered to Dynamo full load	120
" " " Line " "	113
" " " Motor " "	107
" " " Motor pulley " "	100



POWER MEASUREMENTS OF ALTERNATING CURRENTS.

Fig. 1.

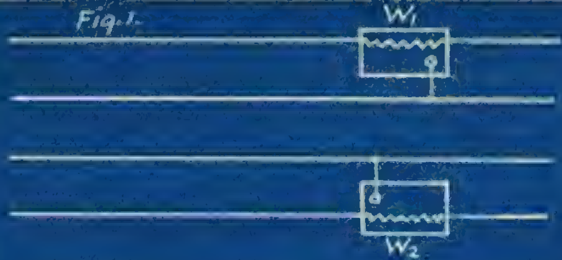
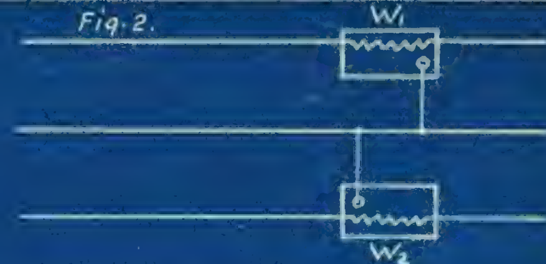


Fig. 2.



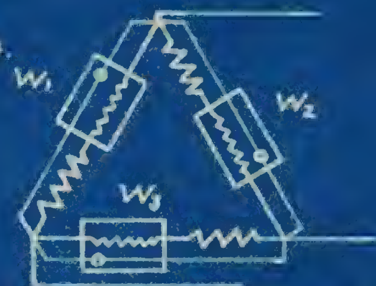
2 PHASE, 4 WIRE:- Independent measurement of Power of each phase
$P = W_1 + W_2$.

2 PHASE, 3 WIRE:- Total Power = Sum of Two Readings.
$P = W_1 + W_2$.

In either of above systems, if there is perfect balance, total power = twice power measured by one wattmeter.

Fig. 3.

Fig. 4.



3 PHASE, Y SYSTEM:- Total Power = Sum of Readings.
$P = W_1 + W_2 + W_3$.

3 PHASE, DELTA SYSTEM:- Total Power = Sum of Readings.
$P = W_1 + W_2 + W_3$.

In either of above systems, if there is perfect balance, total power = three times power measured by one wattmeter.

Fig. 5.

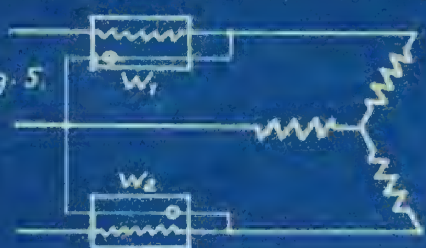


Fig. 6.

In each of above cases of 3-phase systems, Y and Δ, total power = algebraic sum of readings, W_1 and W_2, independent of balance or lag.

(a) If equivalent lag is less than 60°, or power factor greater than 0.50 then, arithmetical sum of readings = power; $P = W_1 + W_2$.
(b) If equivalent lag is greater than 60°, or power factor less than 0.50 then, arithmetical difference of readings = power; $P = W_1 - W_2$.

Check: Interchange instruments without altering relative connections of current and Emf. coils of wattmeters; then,
(a) If deflections are now in same direction as before, sum of original readings = power; $P = W_1 + W_2$.
(b) If deflections are now reversed, difference of original readings = power; $P = W_1 - W_2$.

Fig. 1. Alternating Current Relations.

Effects of Inductance – Lagging Currents.

...ariable Relation of Mean Values: $E_e = \sqrt{E_i^2 - E_s^2}$
...tantaneous values are projections of mean values in
...ral angular positions: $E_e = \Sigma(E_i' \pm E_s')$
... $bc = bd - ab$; and $pr = pq + pr$

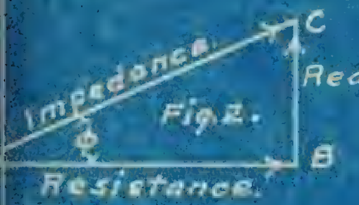


Fig. 2.

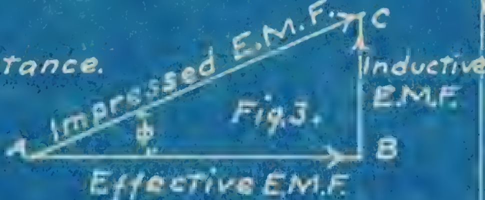


Fig. 3.

Fig. 4.

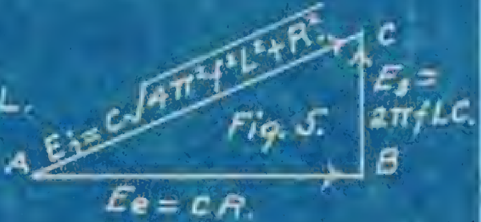
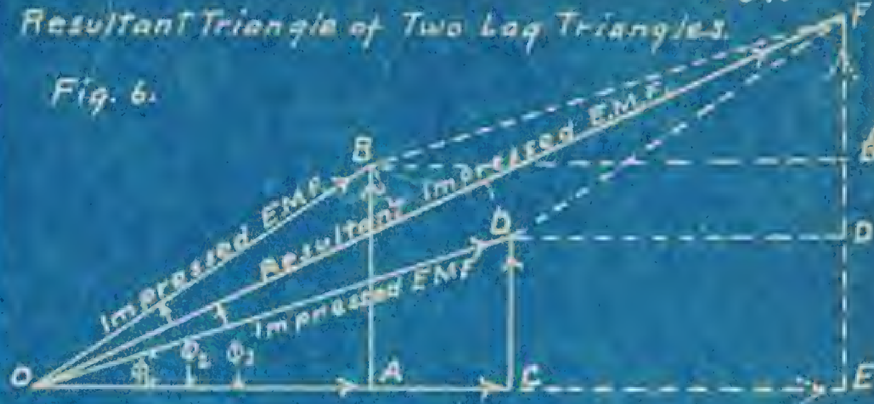


Fig. 5.

...sistance Triangles. E.M.F. Triangles.

Resultant Triangle of Two Lag Triangles.

Fig. 6.



(1a) $OE = OA + OC$. (2a) $EF = AB + CD$.

(1b) $OE = OF \cos\phi_3 = OD \cos\phi_1 + OB \cos\phi_2$.

(2b) $EF = OF \sin\phi_3 = OD \sin\phi_1 + OB \sin\phi_2$.

(3a) OF = geometric sum of OB and OD.

(3b) $OF = OB \cos(\phi_2 - \phi_3) + OD \cos(\phi_3 - \phi_1)$.

(4) $\tan\phi_3 = \dfrac{EF}{OE} = \dfrac{OD \sin\phi_1 + OB \sin\phi_2}{OD \cos\phi_1 + OB \cos\phi_2}$.

$$\underline{\text{Power Factor}} = \cos.\phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{\sqrt{R^2 + 4\pi^2 f^2 L^2}}$$

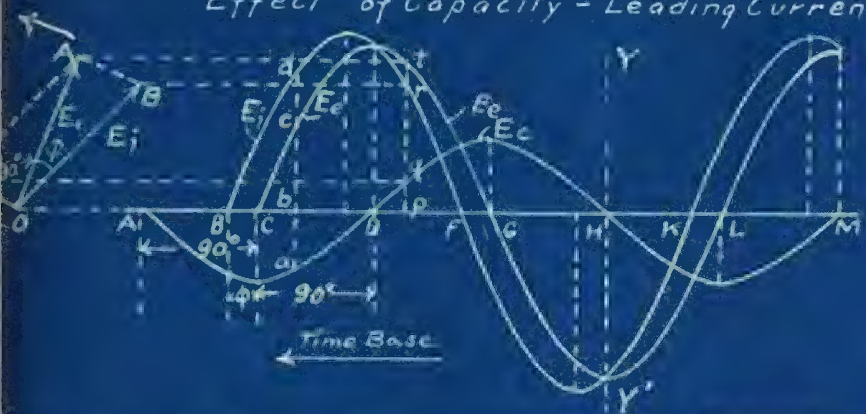
$$\cos\phi = \frac{\text{Effective E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_e}{E_i} = \frac{E_e}{\sqrt{E_e^2 + E_s^2}}$$

$$\underline{\text{Induction Factor}} = \sin\phi = \frac{\text{Reactance}}{\text{Impedance}} = \frac{2\pi f L}{\sqrt{R^2 + 4\pi^2 f^2 L^2}}$$

$$\sin\phi = \frac{\text{Inductive E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_s}{E_i} = \frac{E_s}{\sqrt{E_e^2 + E_s^2}}$$

Fig. 1. Alternating Current Relations,

Effect of Capacity – Leading Currents.



Resultant Triangle of Two Lead Triangles

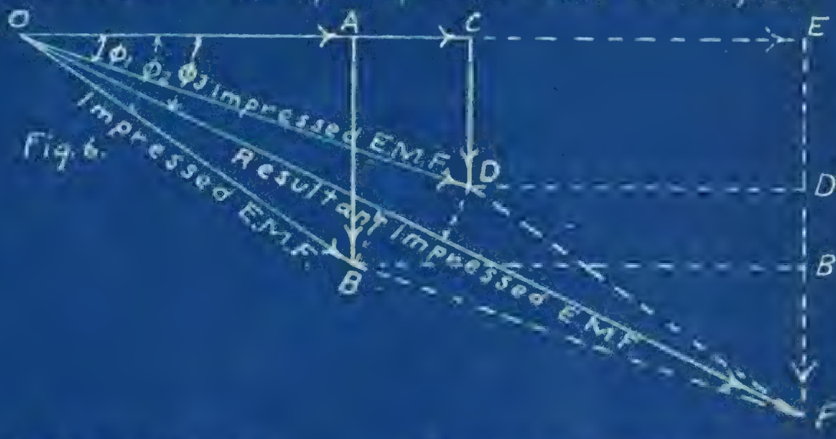


Fig. 6.

...variable Relation of Mean Values: $E_e = \sqrt{E_i^2 - E_c^2}$.

...stantaneous values are projections of mean values in ...eral angular positions: $E_e' = \Sigma(E_i' \pm E_c')$.

...s: $bc = bd - ab$; and, $pt = pr + pq$.

(1a) $OE = OA + OC$. (2a) $EF = AB + CD$.

(1b) $OE = OF\cos\phi_3 = OD\cos\phi_1 + OB\cos\phi_2$.

(2b) $EF = OF\sin\phi_3 = OD\sin\phi_1 + OB\sin\phi_2$.

(3a) OF = geometric sum of OB and OD.

(3b) $OF = OB\cos(\phi_2 - \phi_3) + OD\cos(\phi_3 - \phi_1)$

(4) $\tan\phi_3 = \dfrac{EF}{OE} = \dfrac{OD\sin\phi_1 + OB\sin\phi_2}{OD\cos\phi_1 + OB\cos\phi_2}$

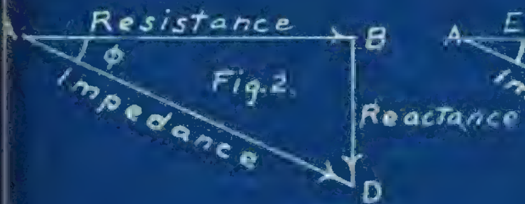


Fig. 2.

Fig. 3.

$$\underline{\text{Power Factor}} = \cos\phi = \frac{\text{Resistance}}{\text{Impedance}} = \frac{R}{\sqrt{R^2 + \frac{1}{4\pi^2 f^2 k^2}}}.$$

$$\cos\phi = \frac{\text{Effective E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_e}{E_i} = \frac{E_e}{\sqrt{E_e^2 + E_c^2}}.$$

Fig. 4.

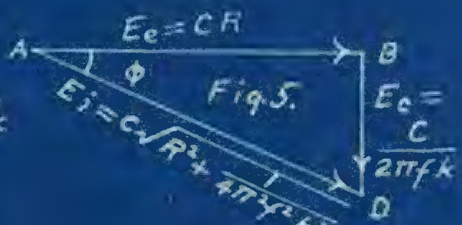
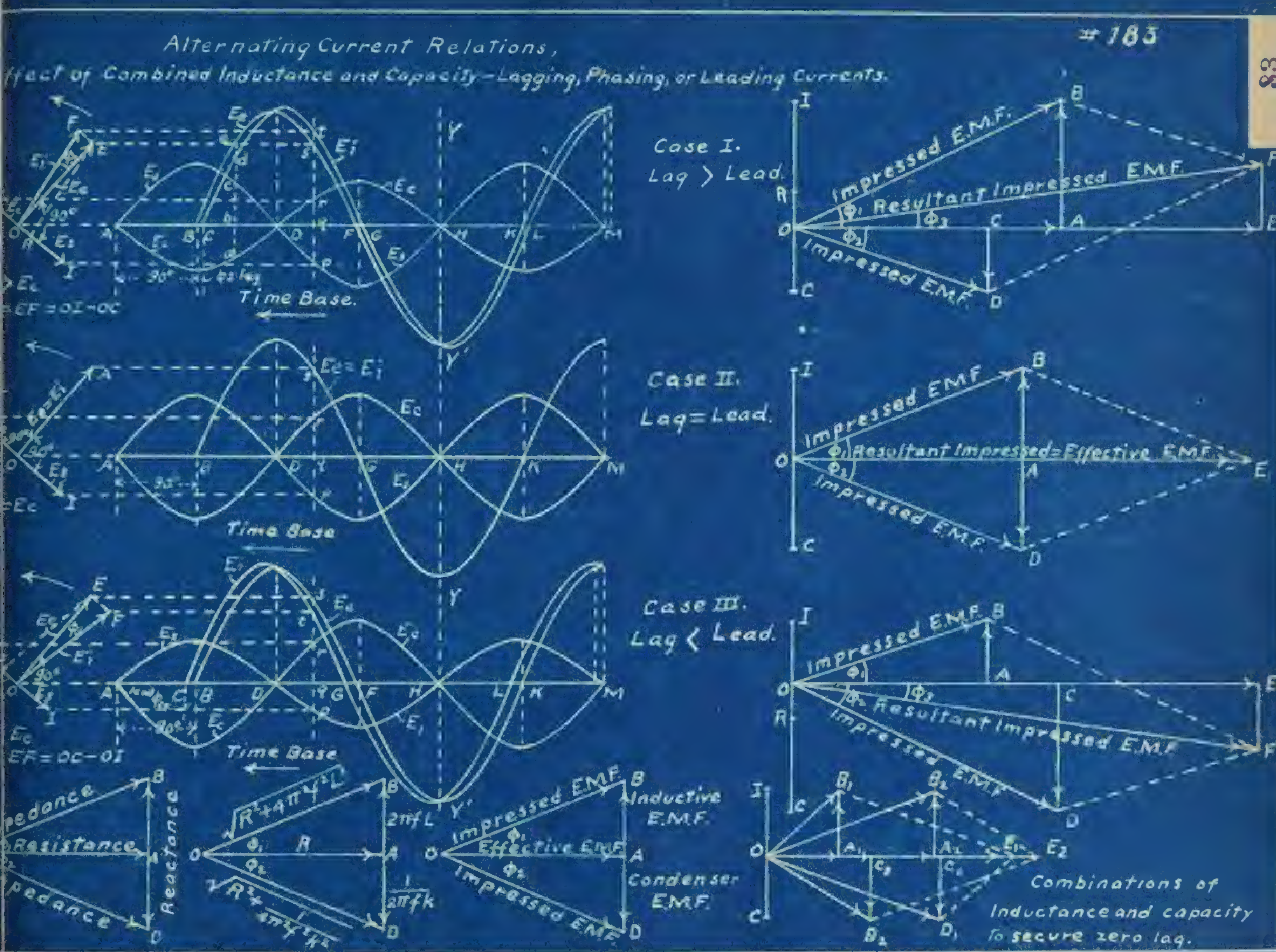


Fig. 5.

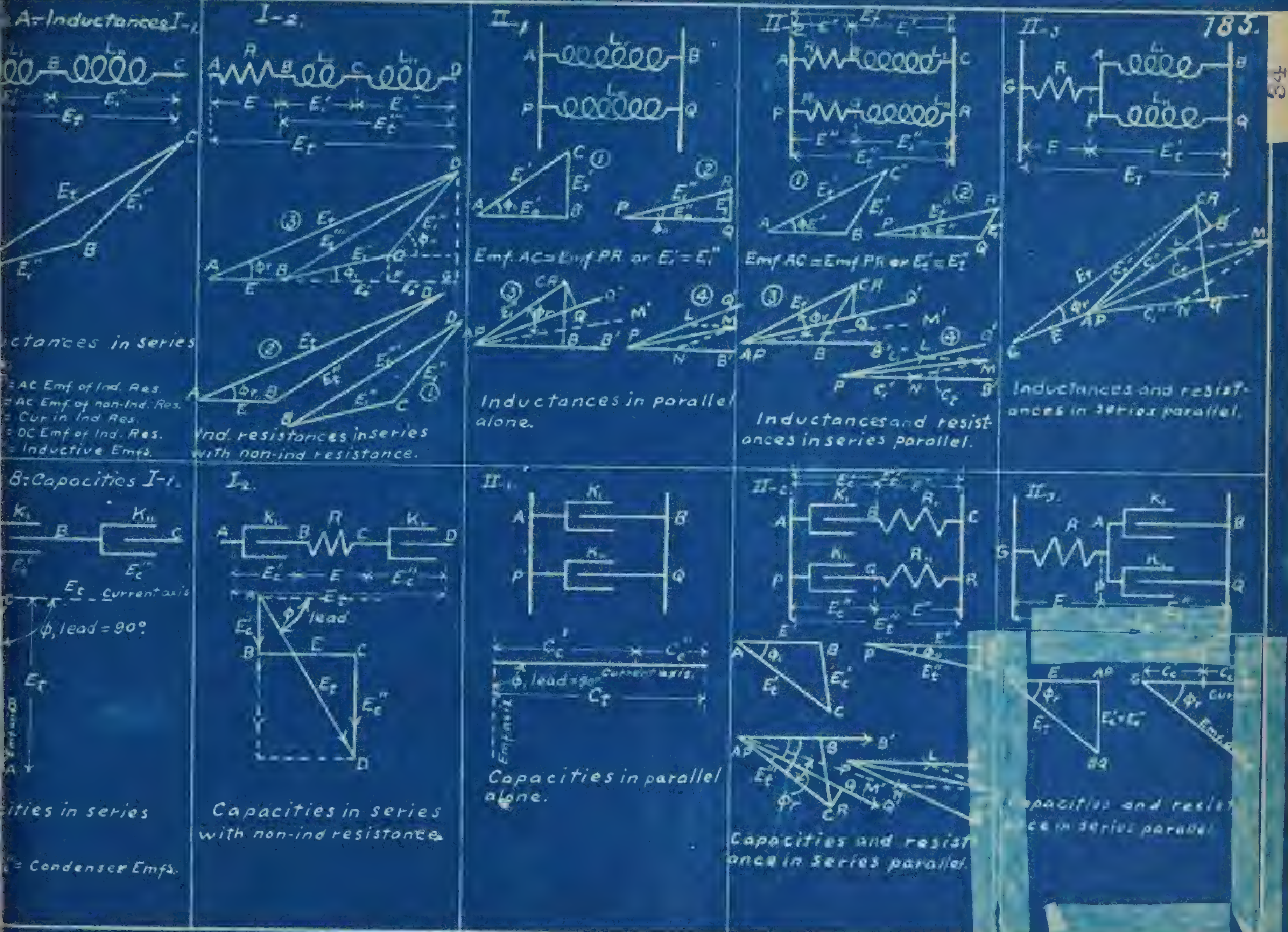
$$\underline{\text{Induction Factor}} = \sin\phi = \frac{\text{Reactance}}{\text{Impedance}} = \frac{\frac{1}{2\pi f k}}{\sqrt{R^2 + \frac{1}{4\pi^2 f^2 k^2}}}.$$

$$\sin\phi = \frac{\text{Condenser E.M.F.}}{\text{Impressed E.M.F.}} = \frac{E_c}{E_i} = \frac{E_c}{\sqrt{E_e^2 + E_c^2}}.$$

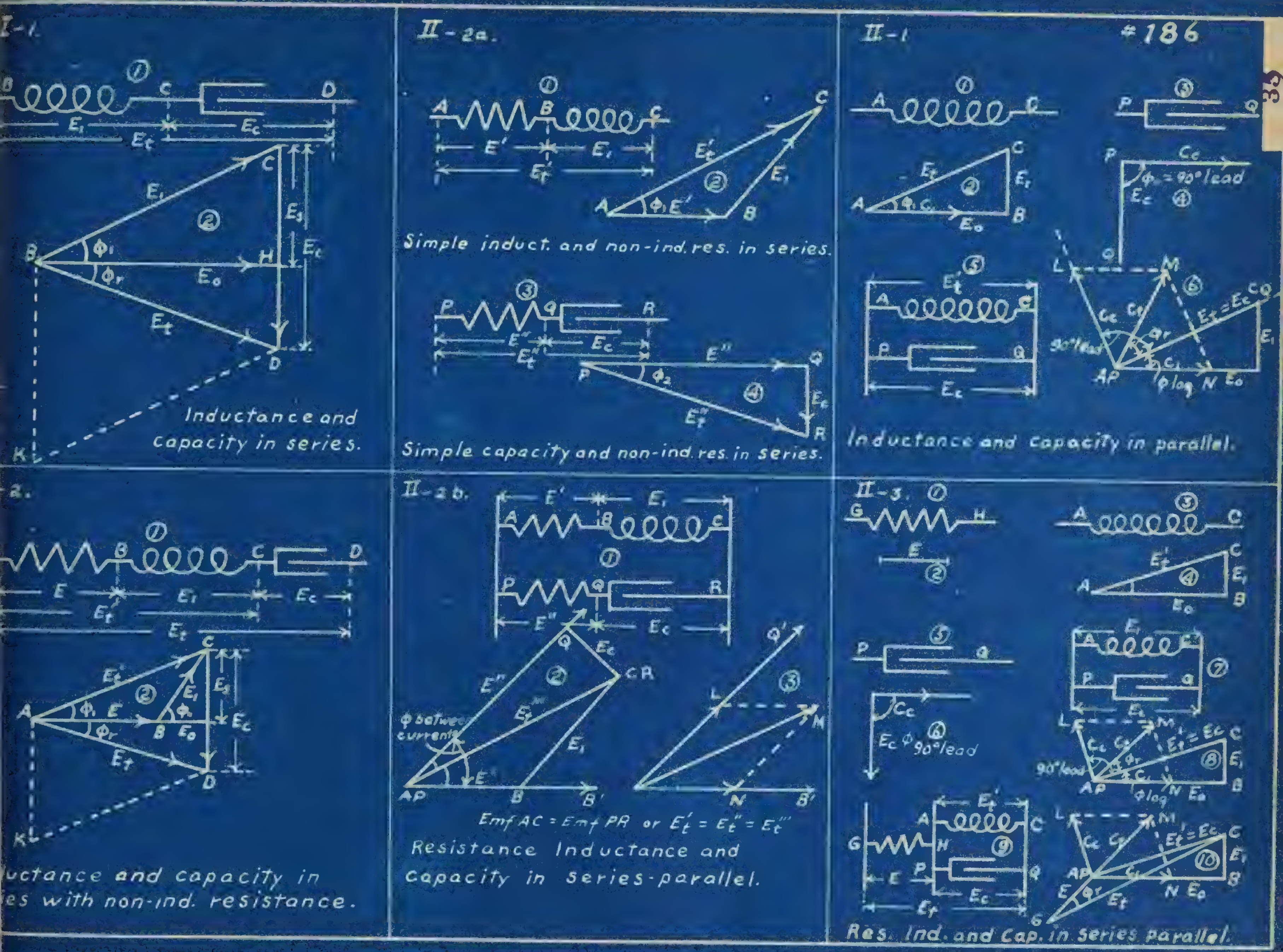
...sistance Triangles. E.M.F. Triangles.

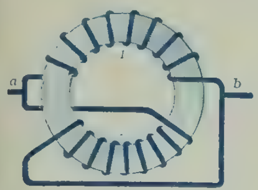


#183
83
Alternating Current Relations,
ffect of Combined Inductance and Capacity—Lagging, Phasing, or Leading Currents.
Time Base.
Time Base
Time Base
Case I.
Lag > Lead.
Impressed E.M.F.
Resultant Impressed EMF
Impressed E.M.F.
Case II.
Lag = Lead.
Impressed EMF
Resultant Impressed = Effective EMF
Impressed E.M.F.
Case III.
Lag < Lead.
Impressed E.M.F.
Resultant Impressed E.M.F.
Impressed E.M.F.
pedance
Resistance
pedance
Reactance
Impressed EMF
Effective EMF
Impressed EMF
Inductive E.M.F.
Condenser E.M.F.
Combinations of
Inductance and capacity
to secure zero lag.

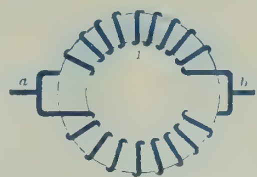


A-Inductances I-1.
...ctances in series
= AC Emf of Ind. Res.
= AC Emf of non-Ind. Res.
= Cur in Ind Res.
= DC Emf of Ind. Res.
= Inductive Emfs.
I-2.
Ind. resistances in series with non-ind resistance.
II-1
Emf. AC = Emf PR or $E_i' = E_i''$
Inductances in parallel alone.
II-2
Emf AC = Emf PR or $E_t' = E_t''$
Inductances and resistances in series parallel.
II-3
Inductances and resistances in series parallel.
B: Capacities I-1.
E_t Current axis
ϕ, lead = 90°
...ities in series
= Condenser Emfs.
I_2.
lead
Capacities in series with non-ind resistance.
II-1.
ϕ, lead = 90° Current axis
Emf axis
Capacities in parallel alone.
II-2.
Capacities and resistance in series parallel.
II-3.
...pacities and resistance in series parallel.

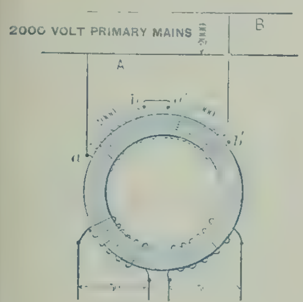

#186
I-1.
Inductance and capacity in series.
I-2.
...uctance and capacity in
...es with non-ind. resistance.
II-2a.
Simple induct. and non-ind. res. in series.
Simple capacity and non-ind. res. in series.
II-2b.
Emf AC = Emf PR or $E_t' = E_t'' = E_t'''$
φ between currents
Resistance Inductance and
capacity in series-parallel.
II-1
$\phi_c = 90°$ lead
90° lead
φ lag
Inductance and capacity in parallel.
II-3.
E_c φ 90° lead
90° lead
φ lag
Res. Ind. and Cap. in series parallel.



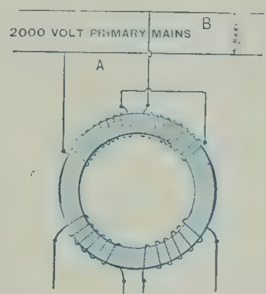
Coils additive.



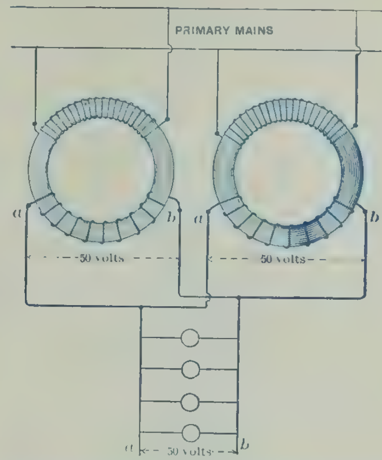
Coils opposed.



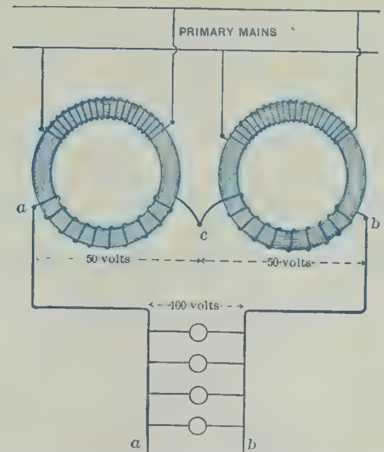
Correct connection of primaries in series.



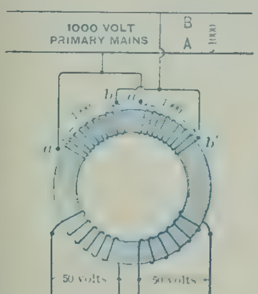
Incorrect connection of primaries in series.



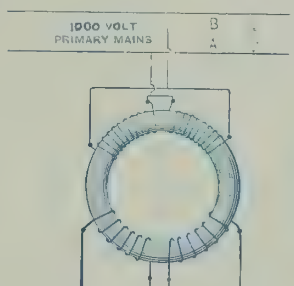
"Banking" transformers: secondaries connected in parallel.



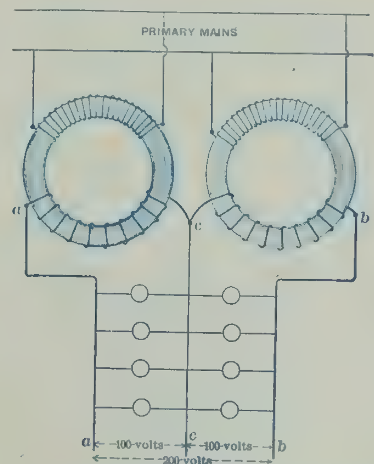
Two 50-volt secondaries connected in series to supply 100-volt lamps.



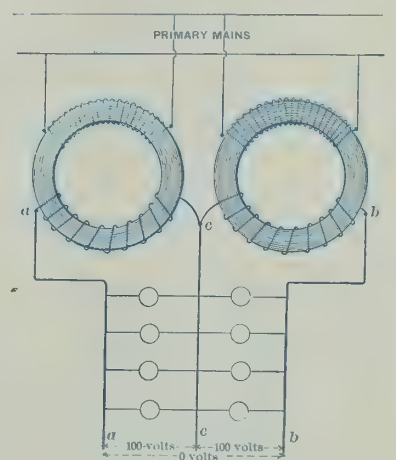
Correct connection of primaries in parallel.



Incorrect connection of primaries in parallel.



Transformers connected for three-wire system.



Incorrect connection for three-wire system.

Correct and Incorrect Connections of Transformers. Bedell's "Principles of the Transformer."

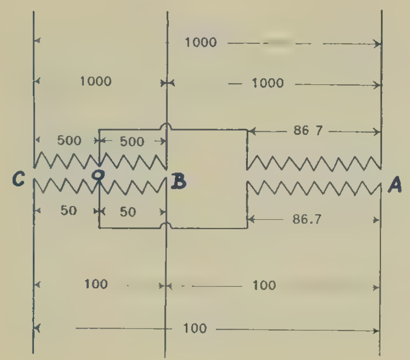
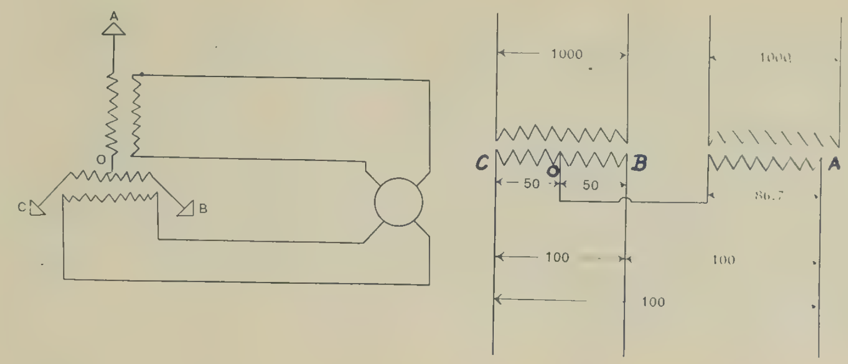
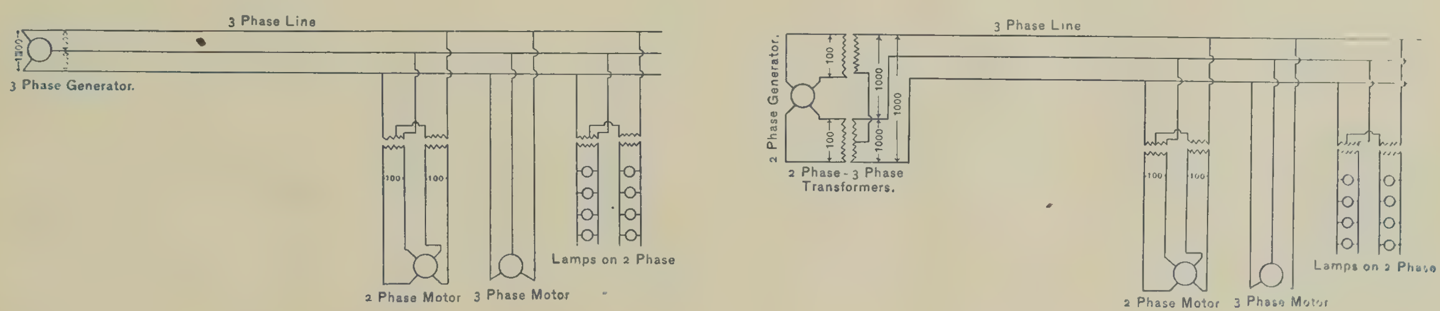


Fig. 1, Transformation in voltage but not in phase.



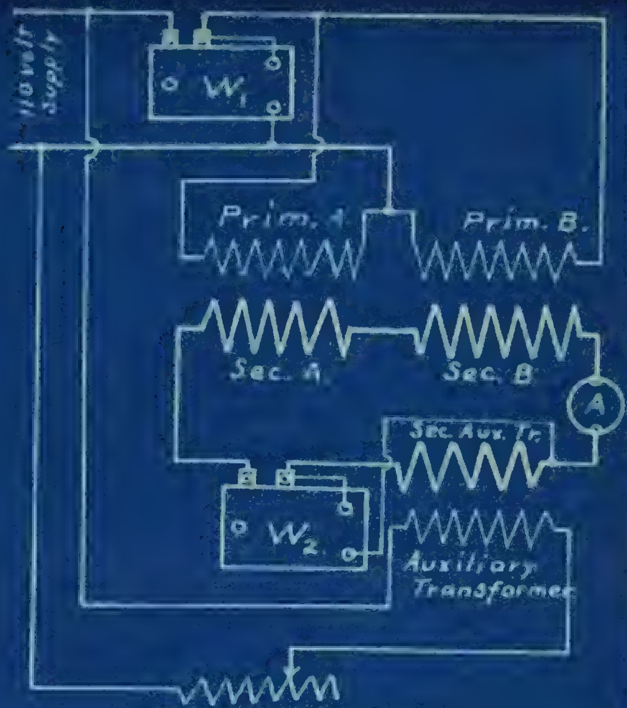
Figs. 2 and 3, Scott system: Transformation in both voltage and phase.



Figs. 4 and 5, Two- or Three-phase Generation and Utilization with Three-phase Transmission.

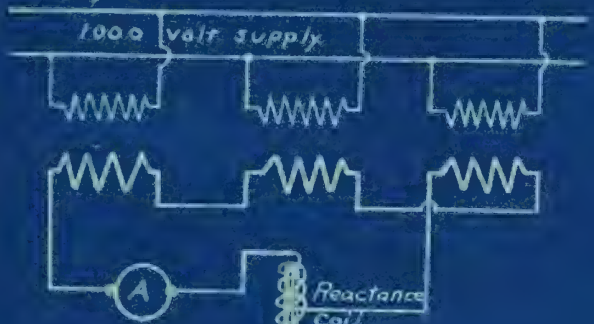
Fig. 3.

Double Voltage Test for Insulation Strength between Turns.



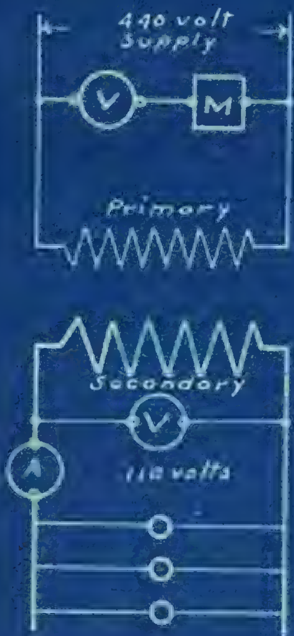
SUMPNER'S METHOD
For determining efficiency and losses.

Fig. 2.



Heating Test by Opposition Method

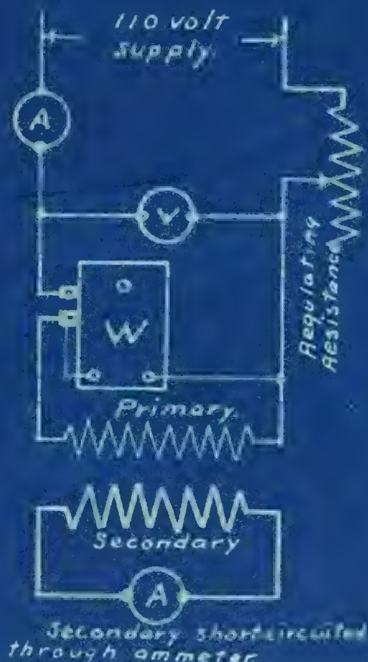
Fig. 4.



REGULATION TEST.

For percent. drop in secondary voltage between no load and given load.

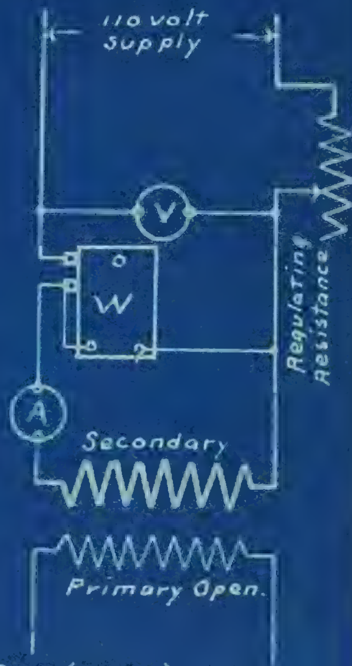
Fig. 5.



COPPER LOSS.

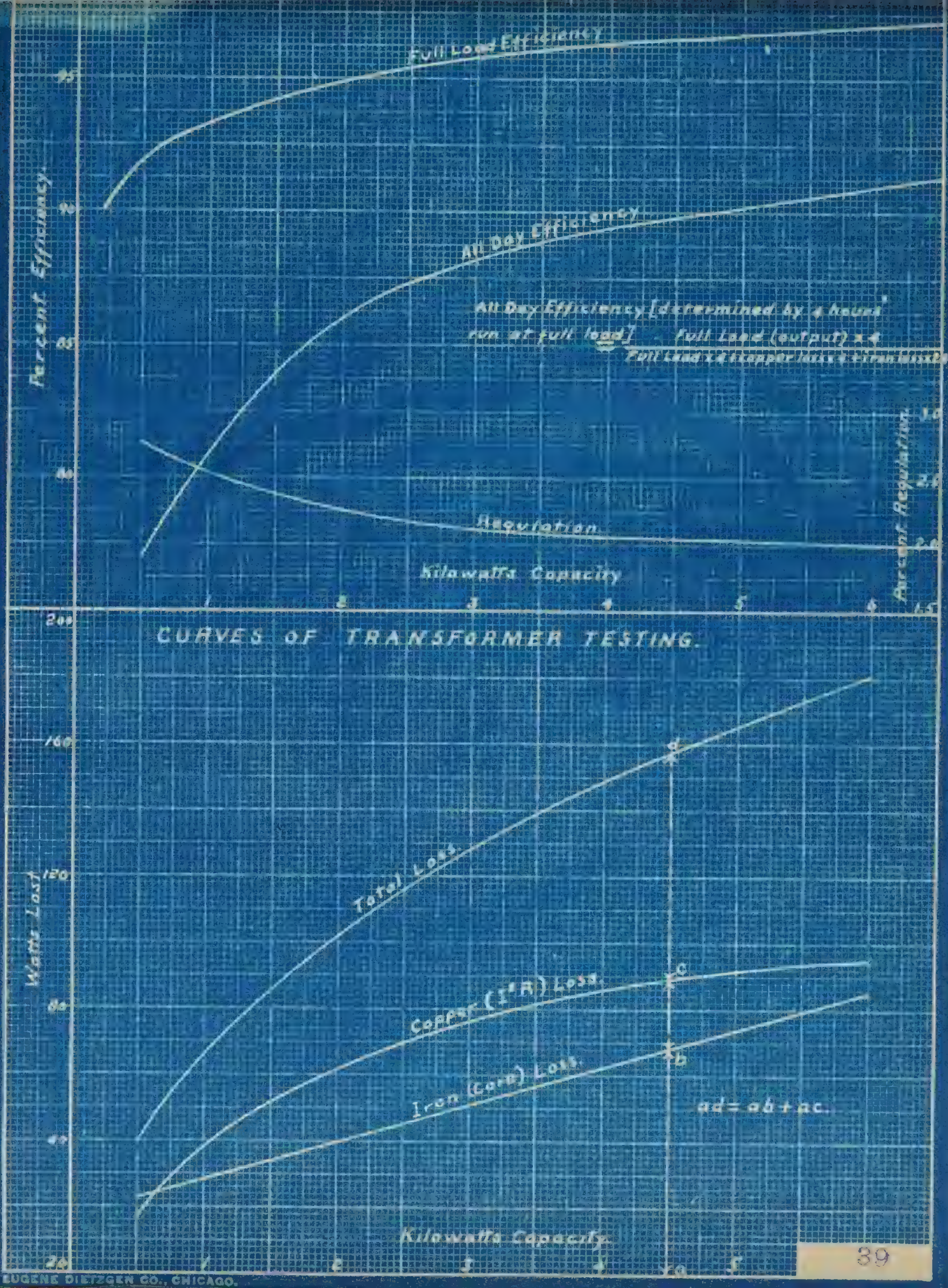
By wattmeter at given load through secondary ammeter. Impedance voltage by voltmeter.

Fig. 6.

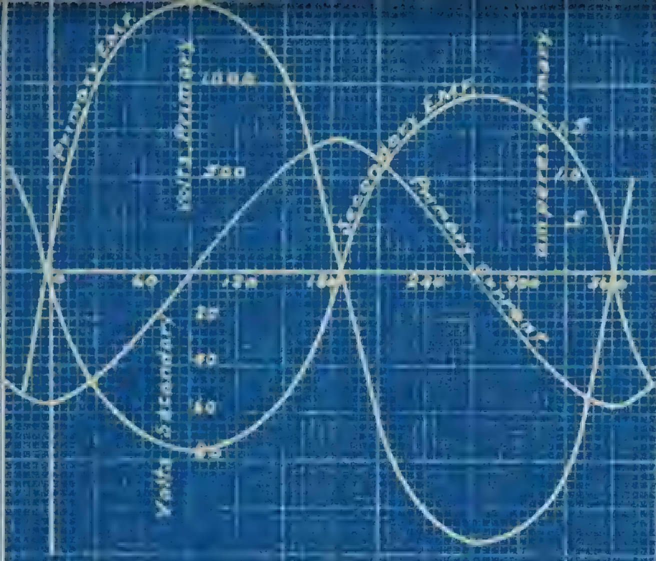


IRON (CORE) LOSS.

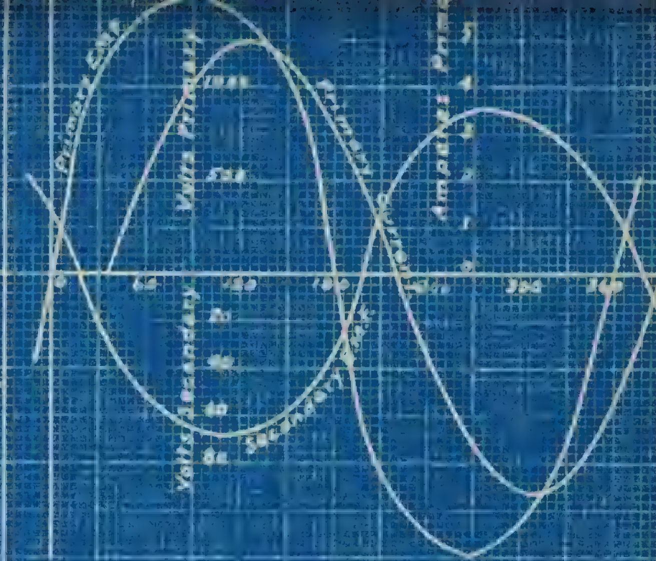
By wattmeter, Exciting current by ammeter.



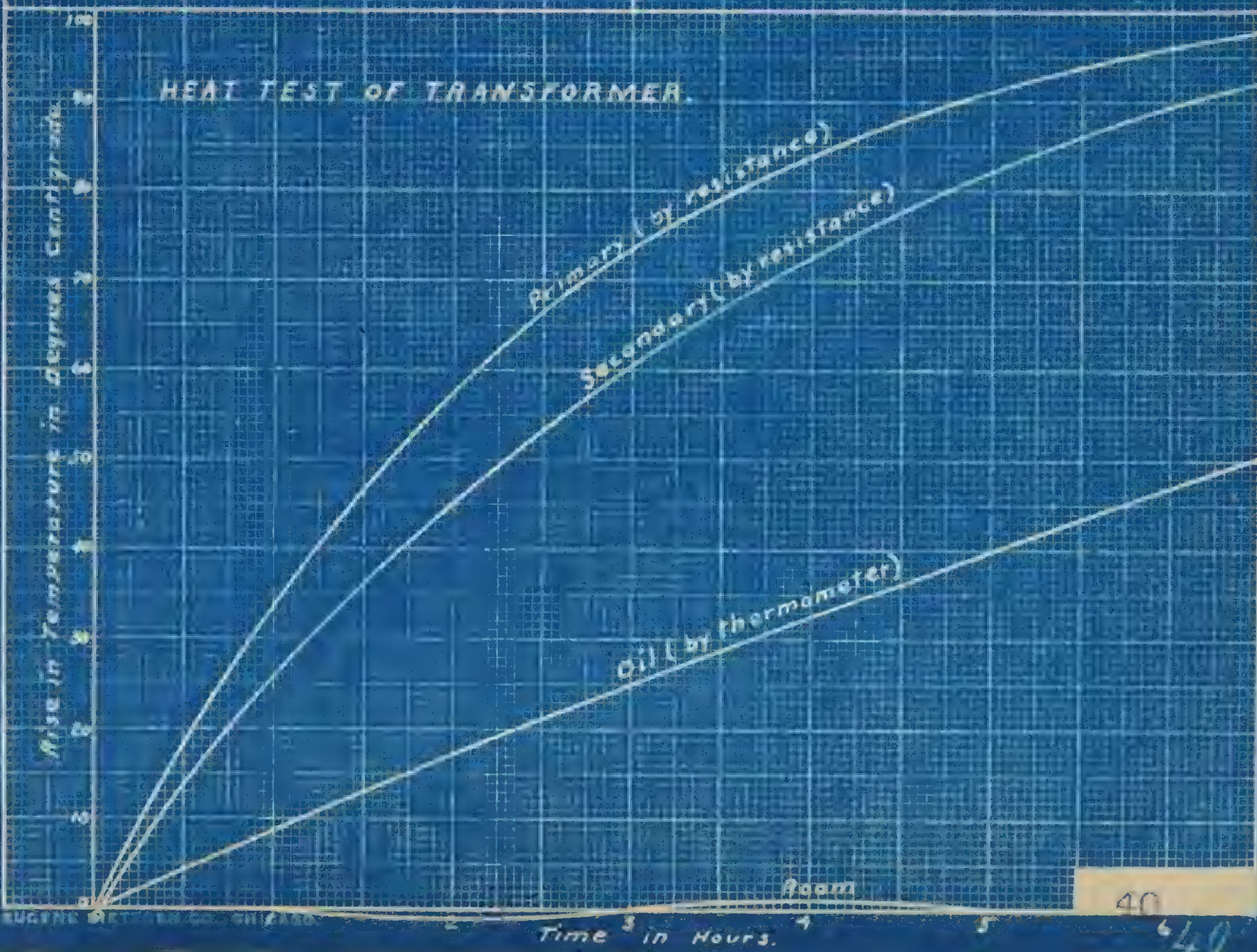
CURVES OF TRANSFORMER TESTING.
Full Load Efficiency
All Day Efficiency
All Day Efficiency [determined by 4 hours' run at full load] = Full Load (output) x 4 / Full Load x 4 + copper loss x 4 + iron loss x 24
Regulation
Percent Efficiency
Percent Regulation
Kilowatts Capacity
Total Loss
Copper (I^2R) Loss
Iron (core) Loss
ad = ab + ac.
Watts Lost
EUGENE DIETZGEN CO., CHICAGO.



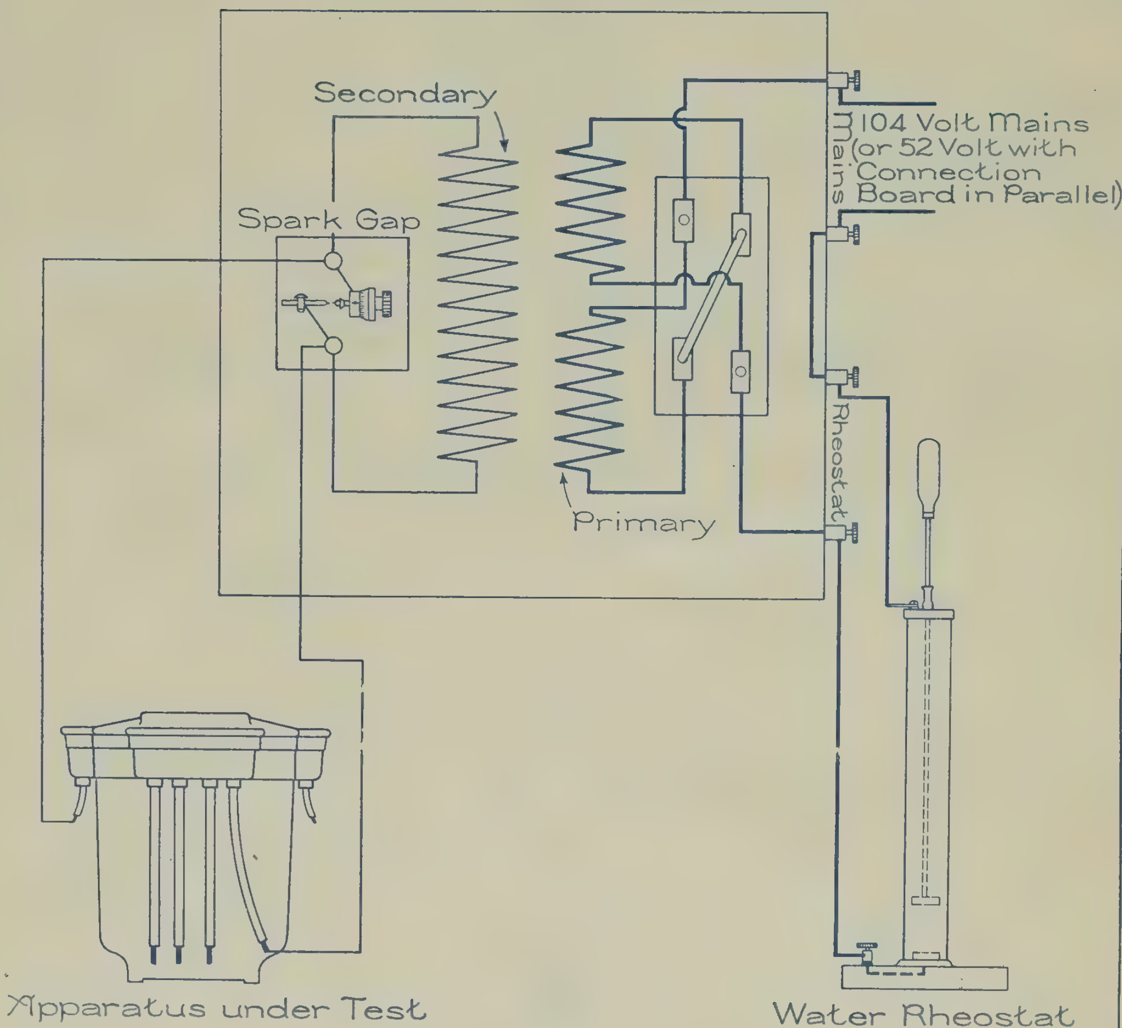
Curves from 60-light Transformer.
Primary Volts, 1000. Watts, 39.6.
Secondary Volts, 50. Watts, 0.
Frequency 130. No Load.



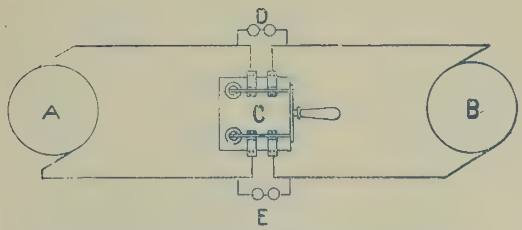
Curves from 60-light Transformer.
Primary Volts, 1000. Watts, 3616.
Secondary Volts, 50. Watts, 3471.
Frequency 130. Full Load.



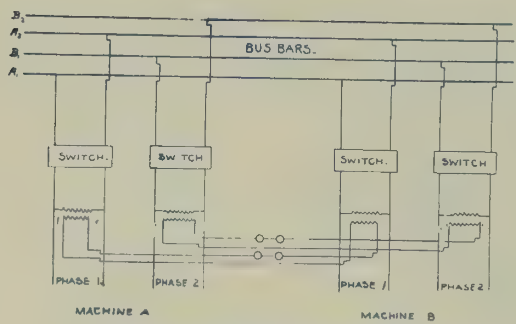
CONNECTIONS OF HIGH POTENTIAL TESTING TRANSFORMER 10000 VOLTS



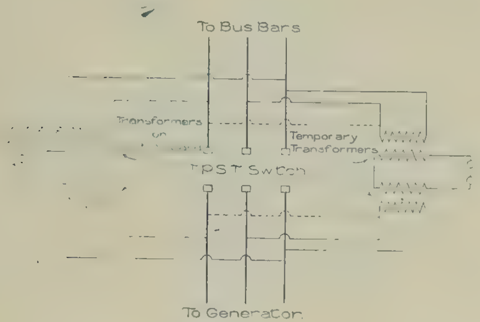
General Electric Co.

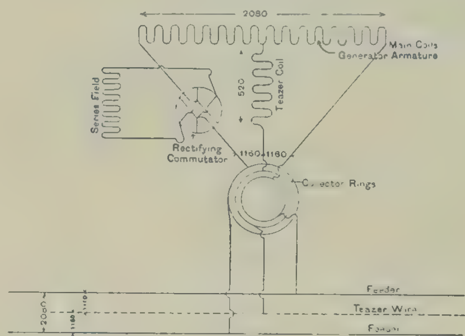


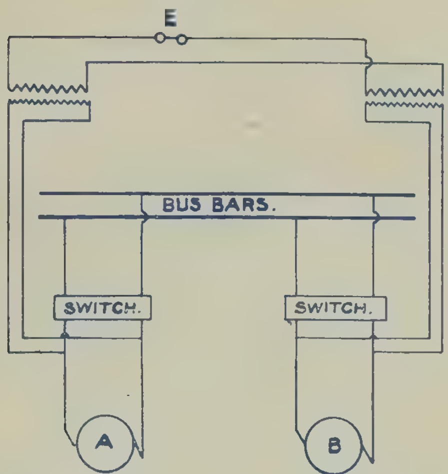
Connections for Paralleling Low Voltage Single Phase Generators.



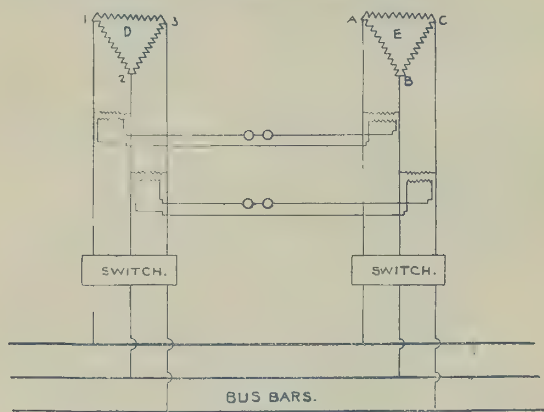
Connections for Paralleling Two-Phase High Voltage Generators.







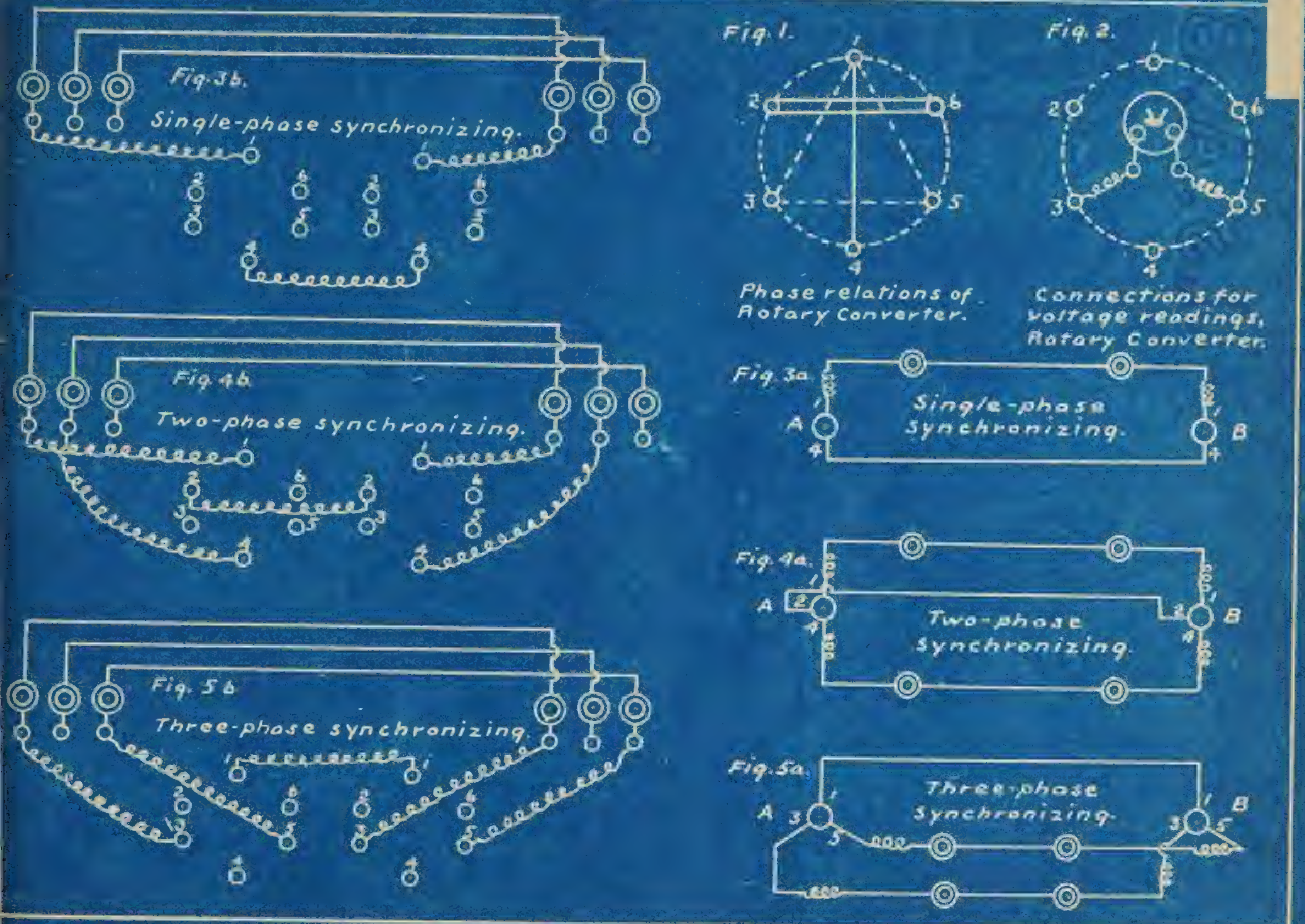
Connections for Paralleling High Voltage Single Phase Generators.

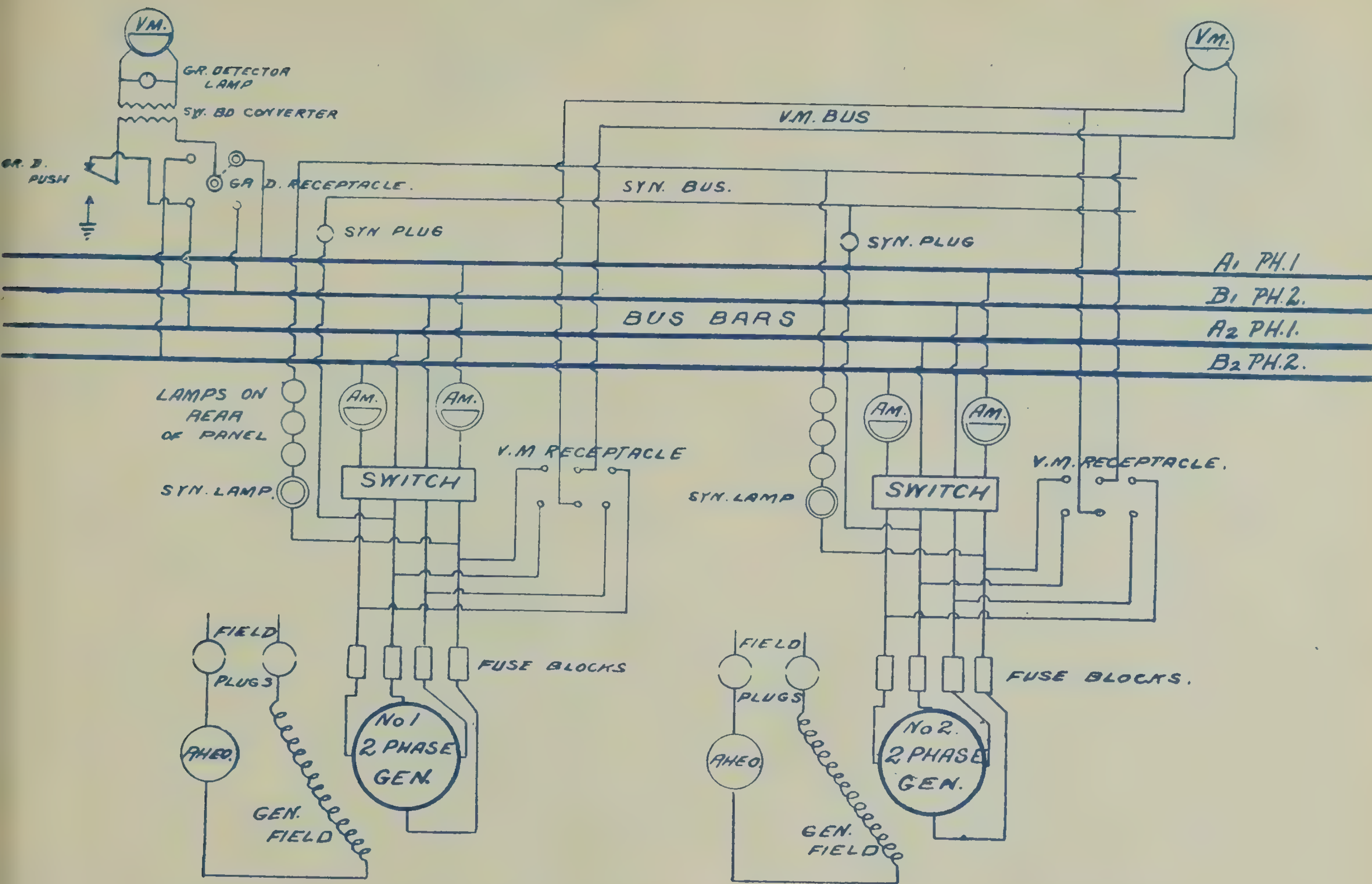


Connections for Paralleling Three-Phase High Voltage Generators.

INSTRUCTION BOOKS,- General Electric Co. and Westinghouse Electric and Manufacturing Co.

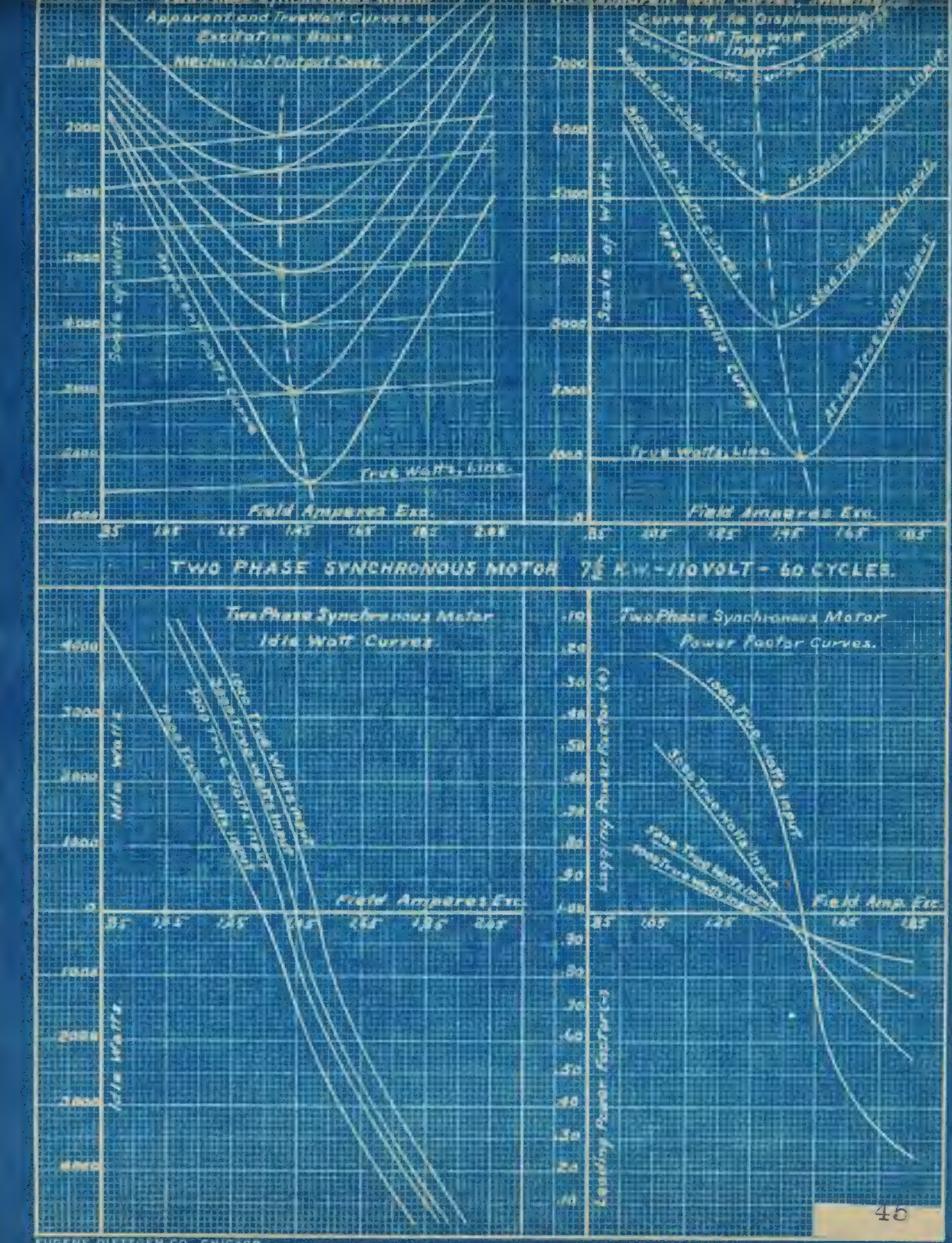
SYNCHRONIZING ARRANGEMENTS, LABORATORY POLYPHASE SWITCHBOARD.

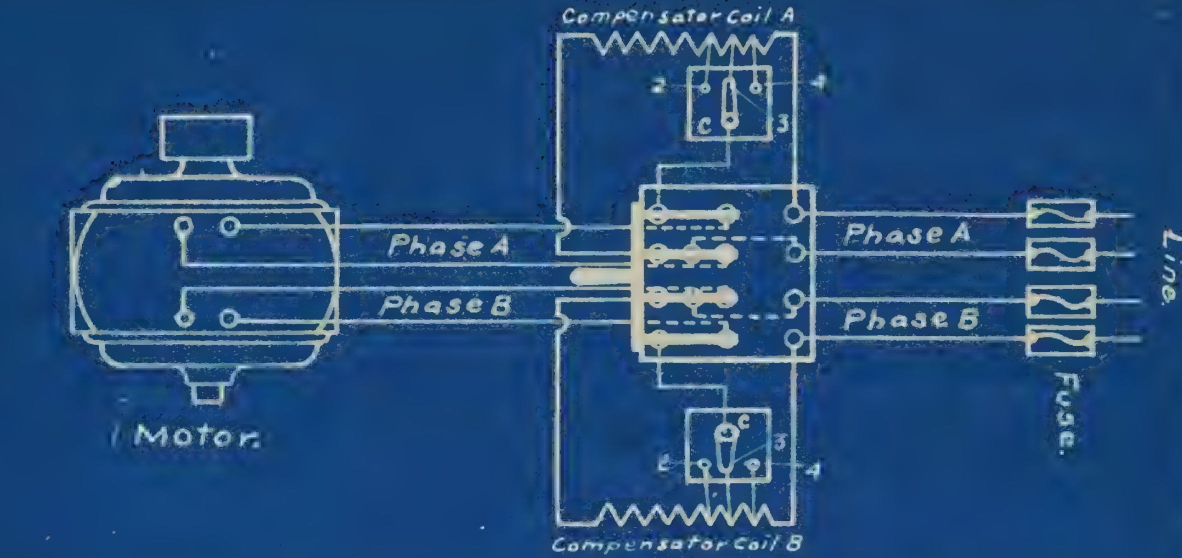




CONNECTIONS FOR MULTIPLE RUNNING OF TWO 440 VOLT GENERATORS.

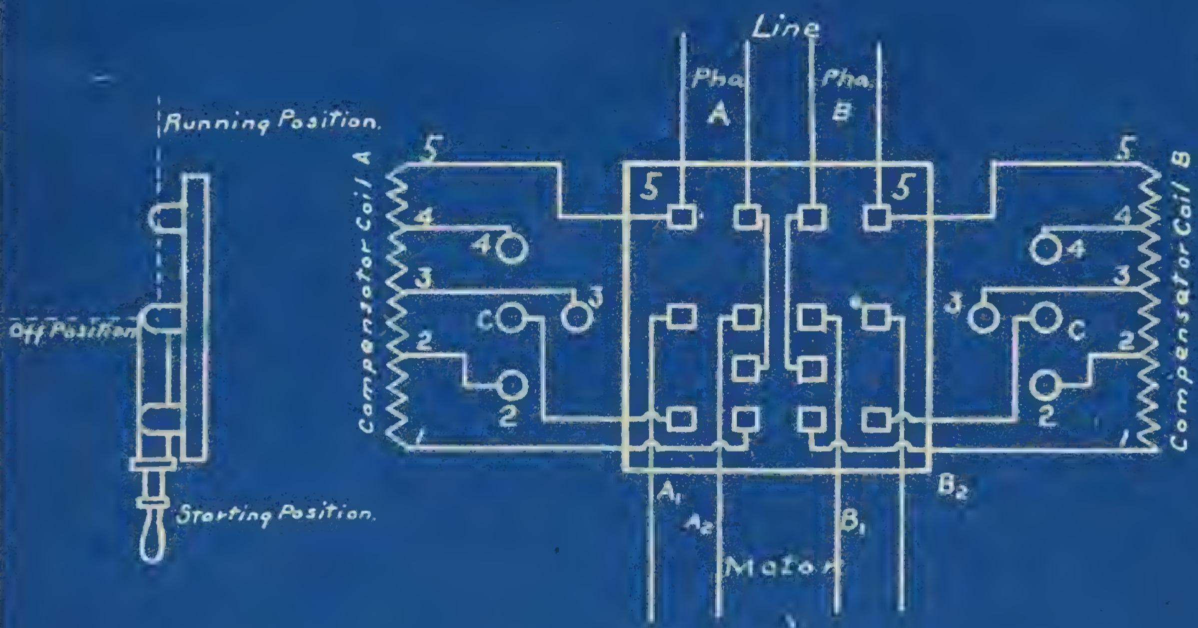
WESTINGHOUSE ELECTRIC AND MANUFACTURING COMPANY.


Apparent and True Watt Curves
Mechanical Output Const.
Scale of Watts
True watts Line.
Field Amperes Exc.
Const True watt Input
Apparent Watts Curves
True watts Line.
Field Amperes Exc.
TWO PHASE SYNCHRONOUS MOTOR 7½ K.W.-110 VOLT - 60 CYCLES.
Two Phase Synchronous Motor
Idle Watt Curves.
Idle Watts
Field Amperes Exc.
Two Phase Synchronous Motor
Power Factor Curves.
Lagging Power Factor
Leading Power Factor
Field Amp. Exc.



Switch and Compensator Connections for Starting Westinghouse Two-phase Ind. Motor.

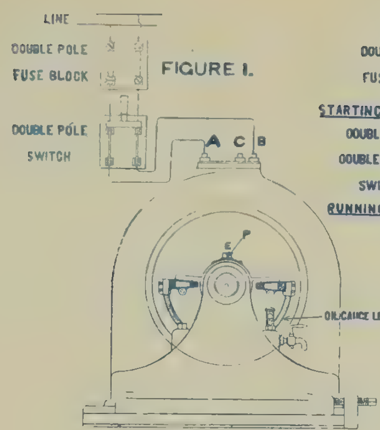
In above diagram switch is thrown to left for starting, and to right for running.



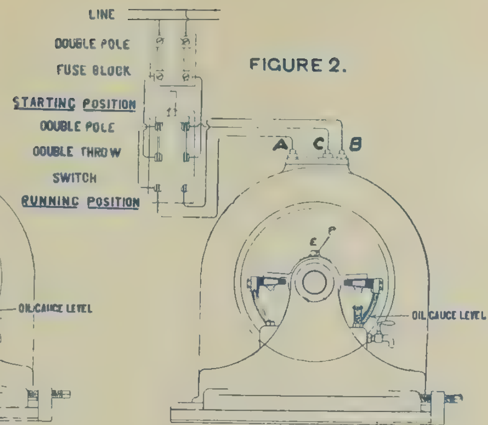
Detail of Compensator Connections.

Variable starting E.M.F. and torque obtained by connecting C to 2, 3, or 4.

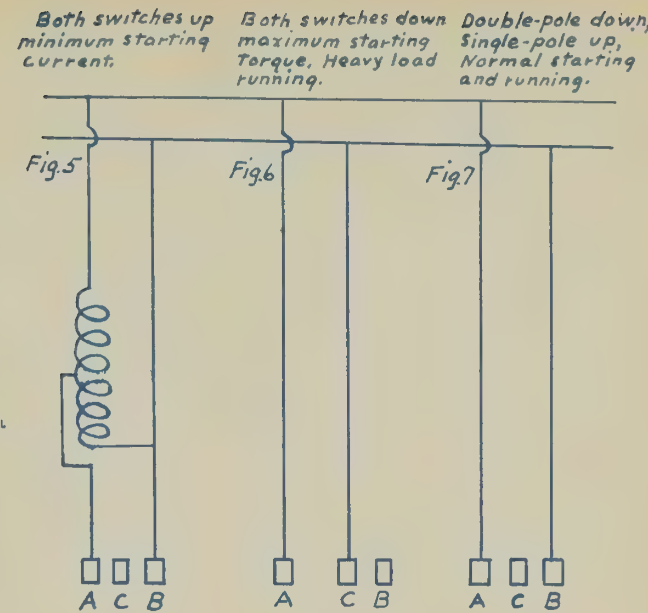
C to 4 gives maximum E.M.F. and torque.
C to 3 " medium " " "
C to 2 " minimum " " "

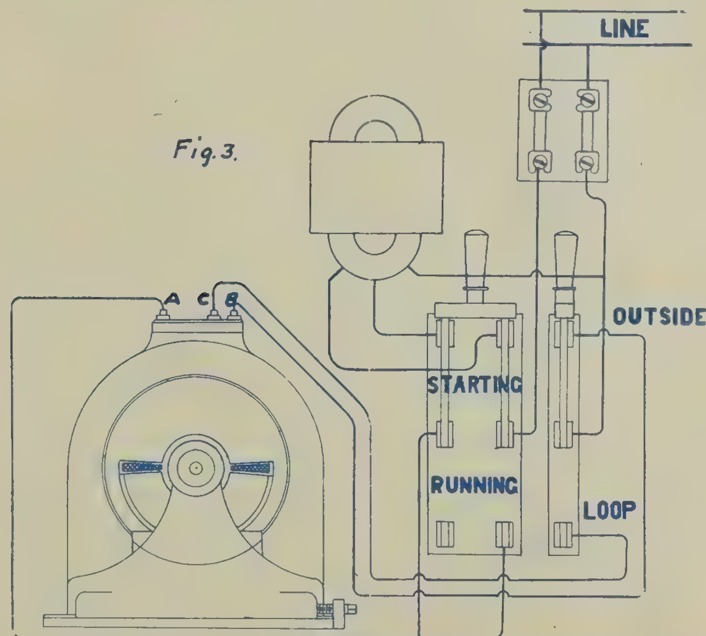


Connections for Normal Torque.

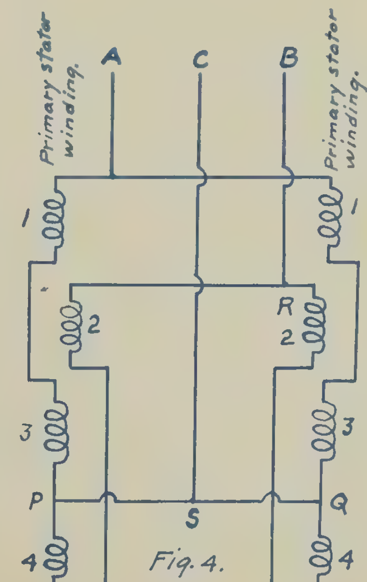


Connections for Abnormal Starting Torque.

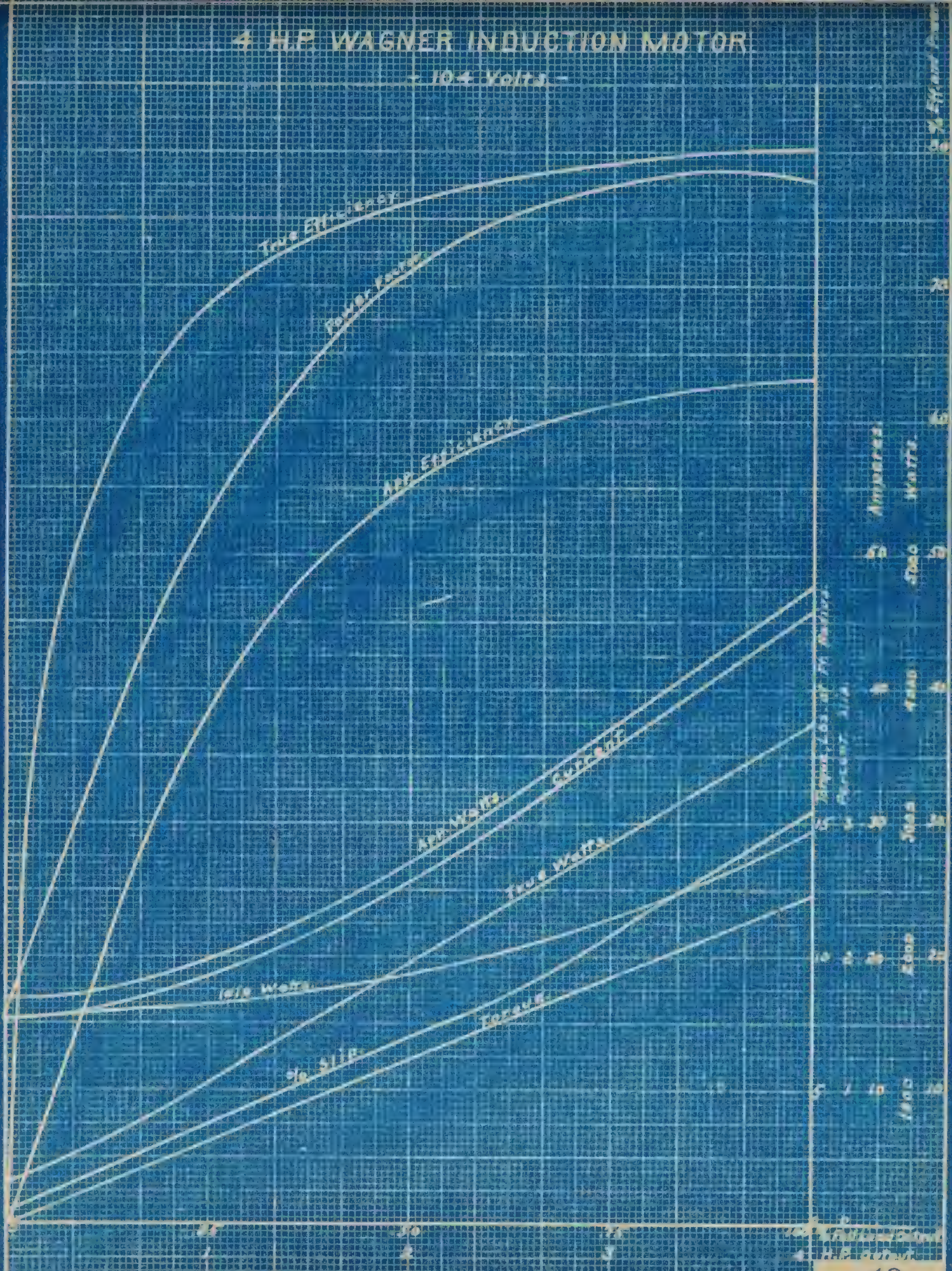




Connections when a Small Reducing Transformer for Holding Down the Starting Current.



Connections of WAGNER INDUCTION MOTOR for Various Operating Conditions.


4 H.P. WAGNER INDUCTION MOTOR
- 104 Volts -
True Efficiency
Power Factor
App. Efficiency
App. Watts
Current
True Watts
Idle Watts
% Slip
Torque
Amperes
Watts

COMPOSITE ELECTRIC TRANSMISSION.

Bedell's system, U.S. Patents, 645,907, 647,741.

Reference:- E.W.&E. 35: 970 & 984; 30, June, 1900.

Fig. 1.

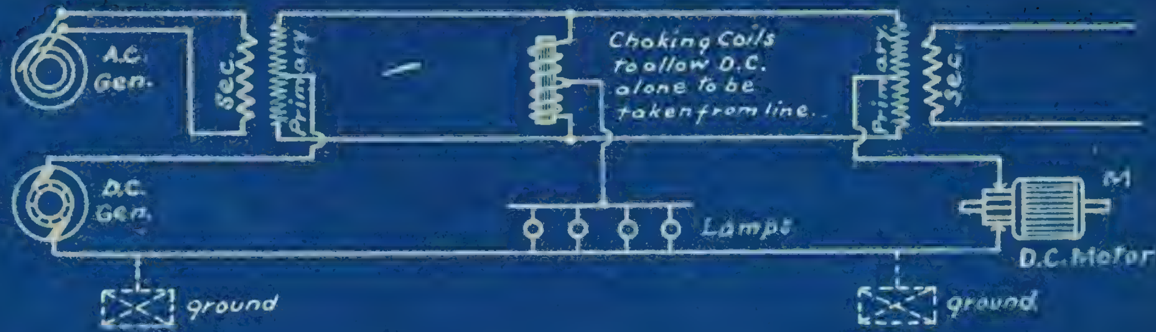


Diagram illustrating Principle, as applied to single phase system. Direct current must pass differentially through primary coils of transformers, and these must have independent primary and secondary circuits.

Fig. 2.

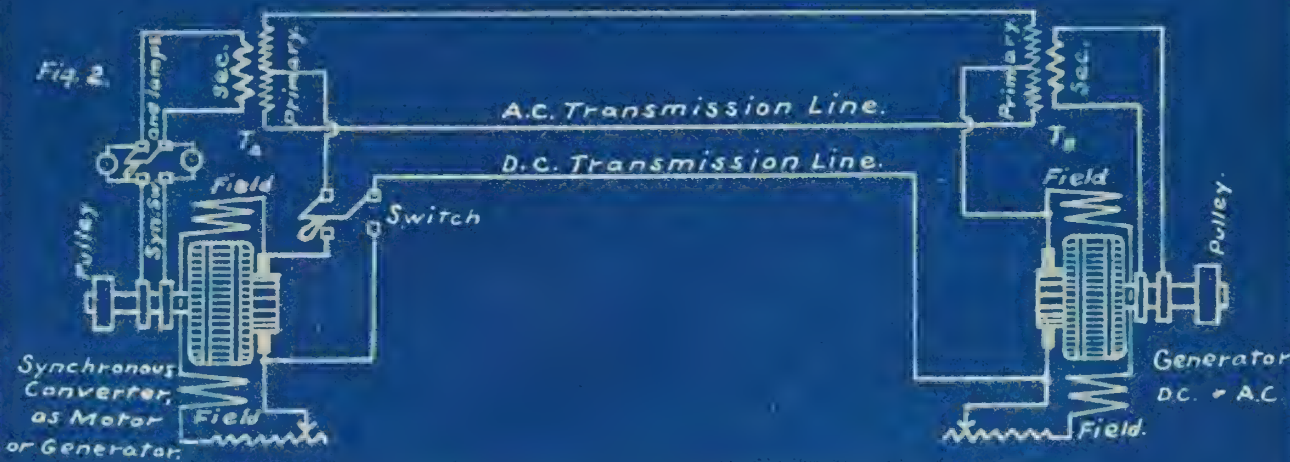
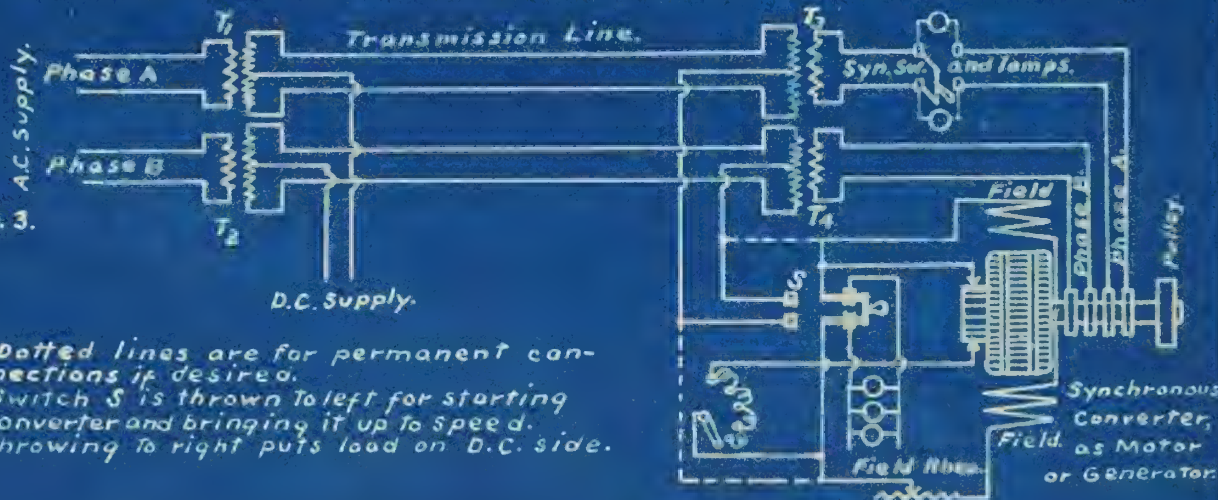


Diagram of Connections for Single-phase System.

STARTING A SYNCHRONOUS CONVERTER BY DIRECT CURRENT TRANSMITTED OVER AN ALTERNATING CURRENT LINE.

Fig. 3.

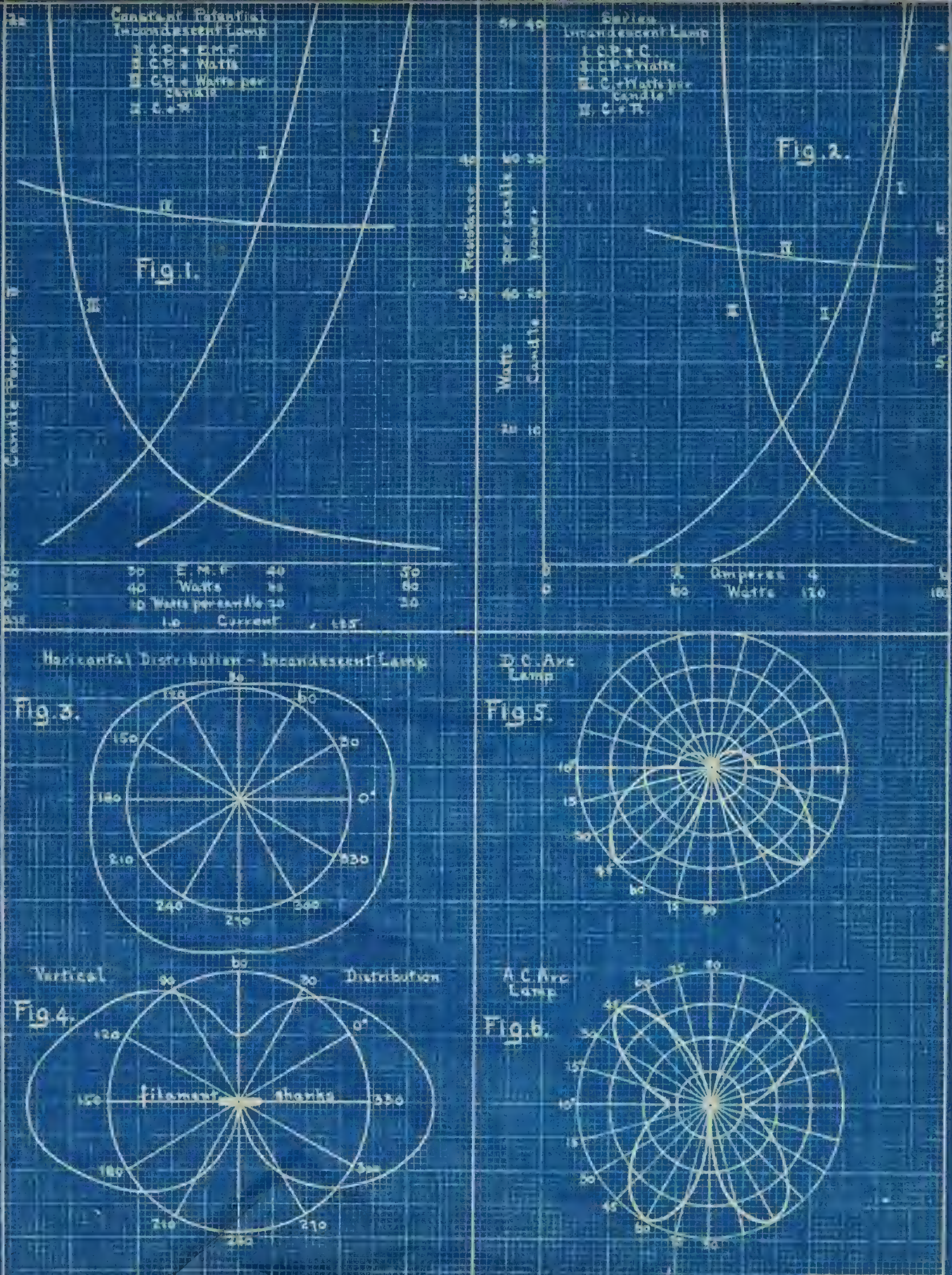


Dotted lines are for permanent connections if desired.
Switch S is thrown to left for starting Converter and bringing it up to speed.
Throwing to right puts load on D.C. side.

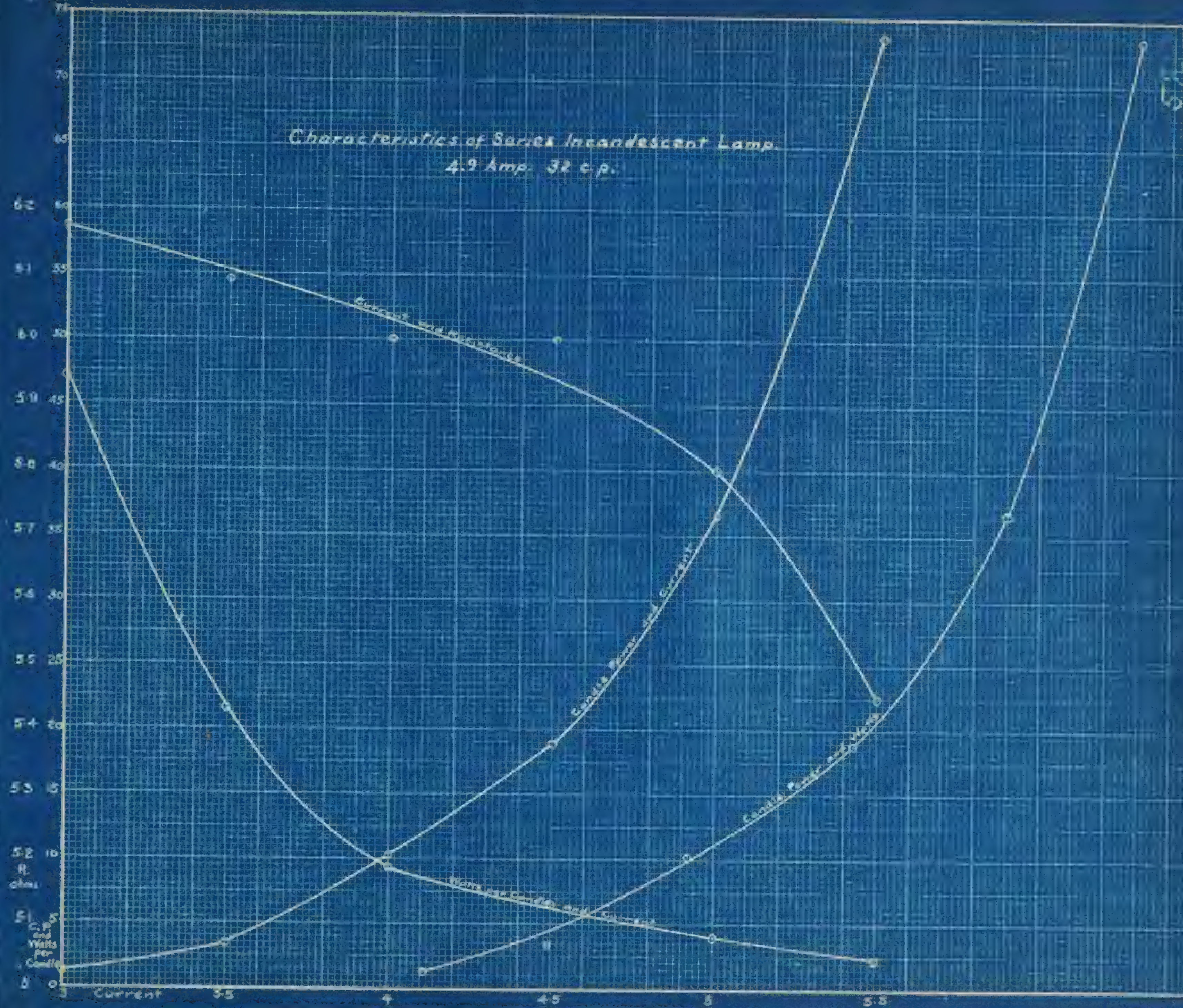
Diagram of Connections for Two-phase System.

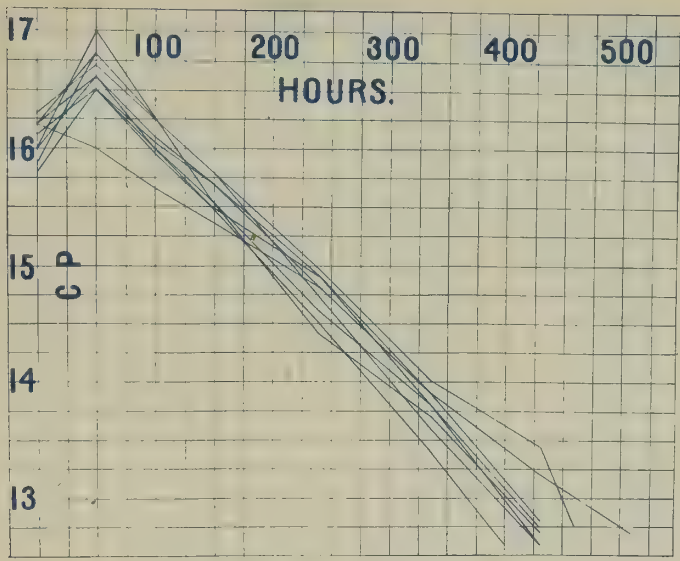
Scale Reading of Bar	0	1	2	3	4	5	6	7	8	9
50	25.0	23.8	22.7	21.7	20.8	19.8	19.0	18.2	17.4	16.7
60	16.0	15.4	14.7	14.2	13.6	13.1	12.6	12.1	11.6	11.2
70	10.8	10.4	10.0	9.7	9.30	9.00	8.69	8.39	8.10	7.83
80	7.56	7.31	7.07	6.84	6.61	6.40	6.19	5.99	5.80	5.62
90	5.44	5.27	5.11	4.95	4.80	4.66	4.52	4.38	4.25	4.12
100	4.00	3.88	3.77	3.66	3.55	3.44	3.35	3.25	3.16	3.07
110	2.98	2.90	2.82	2.74	2.66	2.59	2.52	2.45	2.38	2.31
120	2.25	2.19	2.13	2.07	2.01	1.96	1.91	1.85	1.80	1.76
130	1.71	1.66	1.62	1.58	1.53	1.49	1.45	1.42	1.38	1.34
140	1.306	1.271	1.238	1.205	1.173	1.142	1.113	1.083	1.055	1.027
150	1.000	0.974	0.948	0.923	0.899	0.875	0.852	0.830	0.808	0.787
160	0.765	0.745	0.726	0.706	0.688	0.669	0.652	0.634	0.617	0.601
170	0.585	0.569	0.554	0.539	0.524	0.510	0.496	0.483	0.470	0.457
180	0.444	0.432	0.420	0.409	0.397	0.386	0.376	0.365	0.355	0.345
190	0.335	0.326	0.316	0.307	0.298	0.290	0.282	0.273	0.265	0.258
200	0.250	0.243	0.235	0.228	0.221	0.215	0.208	0.202	0.196	0.190
210	0.184	0.178	0.172	0.167	0.161	0.156	0.151	0.146	0.141	0.137
220	0.132	0.128	0.123	0.119	0.115	0.111	0.107	0.104	0.100	0.096
230	0.093	0.089	0.086	0.083	0.080	0.076	0.074	0.071	0.068	0.065
240	0.063	0.060	0.057	0.055	0.053	0.050	0.048	0.046	0.044	0.042
250	0.040	0.038	0.036	0.035	0.033	0.031	0.030	0.028	0.027	0.025

Table of Light Ratios for a 300-part Photometer Bar.
Ratio of c.p. of lamp under test to c.p. of standard lamp used.

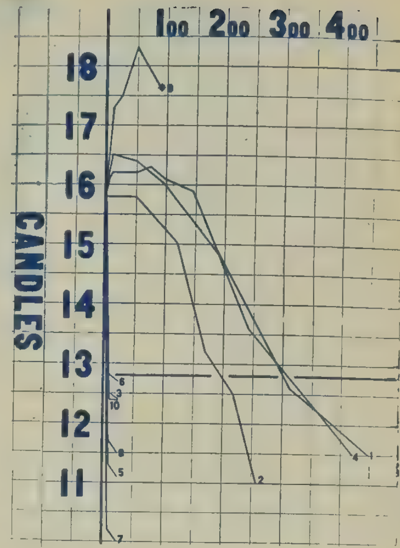


Constant Potential Incandescent Lamp
I C.P. ÷ E.M.F.
II C.P. ÷ Watts
III C.P. ÷ Watts per candle
IV C. ÷ R.
Fig. 1.
Candle Power
E.M.F.
Watts
Watts per candle
Current
Series Incandescent Lamp
I C.P. ÷ C.
II C.P. ÷ Watts
III C. ÷ Watts per candle
IV C. ÷ R.
Fig. 2.
Resistance
Watts per candle
Candle Power
Watts
Amperes
Watts
Horizontal Distribution - Incandescent Lamp
Fig. 3.
Vertical Distribution
Fig. 4.
filament
shanks
D.C. Arc Lamp
Fig. 5.
A.C. Arc Lamp
Fig. 6.

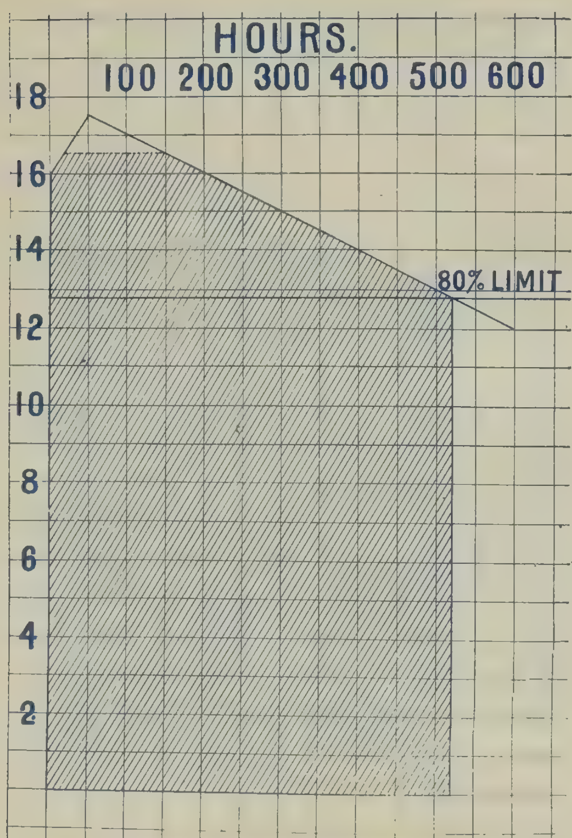

Characteristics of Series Incandescent Lamp
4.9 Amp. 32 c.p.
Current and Resistance
Candle Power and Current
Candle Power and Watts
Watts per Candle and Current
R. ohms
C.P. and Watts per Candle
Current



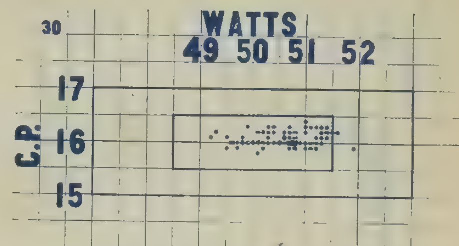
-Candle-power performance of ten 16 candle-power 112-volt 3·1-watt lamps, showing uniform and good results of well-made lamps.



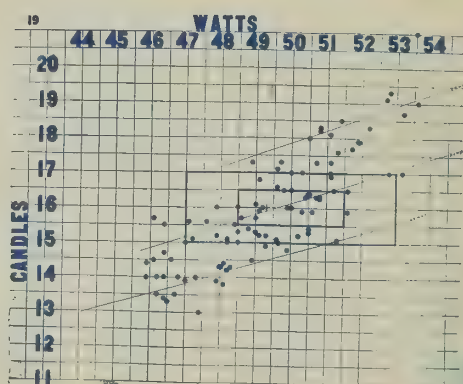
–Candle-power performance diagram, showing poor results give by ten 16-candle-power 100-volt lamps—3½-watt lamps.



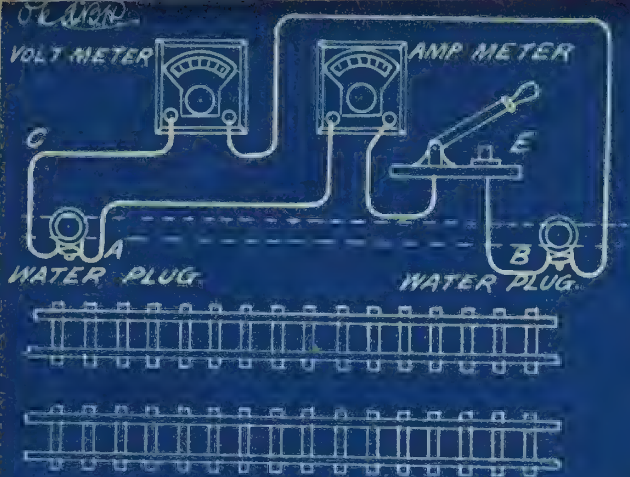
—The candle hour area. The measure of lamp value.



—Target diagram showing results of correctly rated lamps.



-Target diagram showing initial measurements at marked voltage of 100 lamps, rated as 16 candle-power, 50-watt lamps.



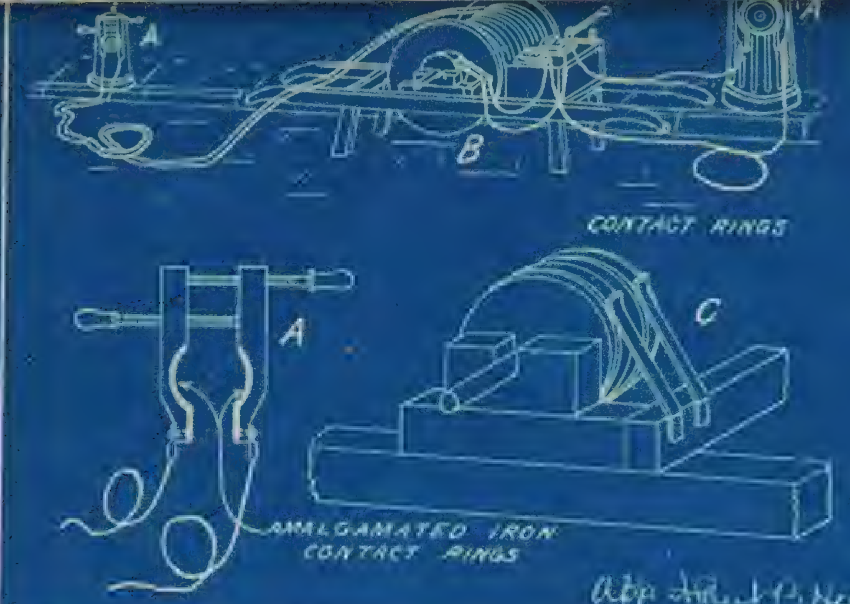
INSTRUMENTS REQUIRED.

1 VOLTMETER READING 5 VOLTS; 1 AMPERE METER READING 15 AMPERES, 600 FEET #6 B & S CABLE, 600 FEET #10 B & S CABLE, 2 PLUG CLAMPS LIKE SHOWN AT A SHEET 2, ONE PORTABLE REEL SHOWN AT B SHEET 2, PROVIDED WITH COMMUTATOR AS SHOWN AT "C". THE REEL IS PROVIDED WITH A SHELF TO WHICH INSTRUMENTS AND SWITCH ARE SECURED.

IF TWO ADJACENT WATER PLUGS WHICH ARE ON THE SAME LINE OF PIPE BE CONNECTED TOGETHER ELECTRICALLY THROUGH AN AMPERE METER, IF THERE IS A CURRENT FLOW THROUGH THE PIPE A PART WILL BE DIVERTED THROUGH THE EXTERNAL AMPERE METER CIRCUIT "A-B" WHEN SWITCH "E" IS CLOSED. IN ORDER TO DETERMINE THE CURRENT FLOW IN WATER PIPE THE FOLLOWING READINGS WILL HAVE TO BE TAKEN. VOLTS WITH SWITCH "E" OPEN V_1.
THEN CLOSE SWITCH "E", AND READ VOLTS AGAIN V_2, ALSO READ AMPERES FLOWING "A", AND CALL THE NORMAL CURRENT FLOW IN PIPE "X". THEN

$$X:A::V_1:V_1-V_2$$

. THIS IS APPROXIMATELY CORRECT. THE RESULTS MAY BE UNRELIABLE FROM THE FOLLOWING CAUSES: THAT THE TWO PLUGS MAY NOT BE ON THE SAME WATER MAIN, THEN THE AMPERE LEADS FORMS A JUMPER BETWEEN THESE TWO PIPES AND THERE IS A VERY SLIGHT CHANGE OF VOLTAGE FOR CONSIDERABLE CURRENT FLOW AND SHOWS APPARENTLY VERY LOW RESISTANCE. A NUMBER OF ADJACENT PLUGS ALONG A STREET SHOULD BE MEASURED IN ORDER TO GET THE AVERAGE CURRENT VALUE. A BAD PIPE JOINT WILL SHOW HIGH VOLTAGE ON OPEN SWITCH AND LARGE CURRENT WITH SMALL DROP IN VOLTAGE WHEN SWITCH "E" IS CLOSED. THERE MAY BE CONSIDERABLE RESISTANCE IN THE LATERAL PIPE CONNECTING THE PLUG TO THE MAIN PIPE, WHEN THIS IS THE CAUSE THE CLOSED



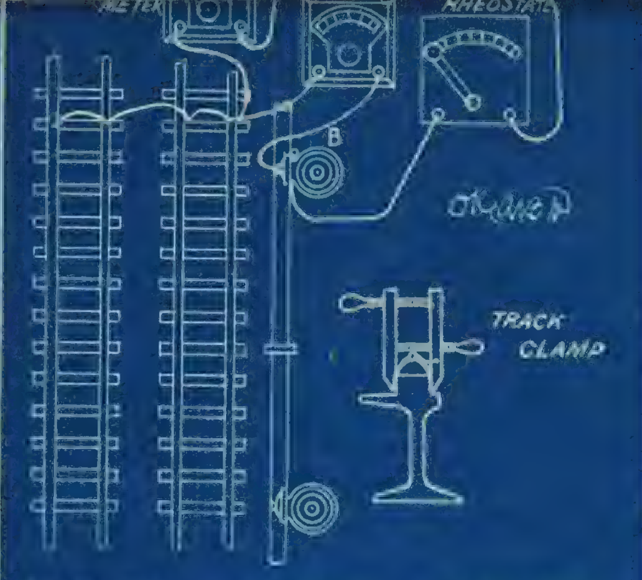
CIRCUIT VOLTS WILL BE LOW AND NO PERCEPTIBLE OR VERY LITTLE CURRENT FLOW, AND ADJACENT PIPE SECTION READINGS WILL NOT APPROXIMATE THE SAME VALUES WHICH THEY SHOULD SHOW.

TEST FOR LOCAL EARTH RESISTANCE BETWEEN PIPE AND RAILS

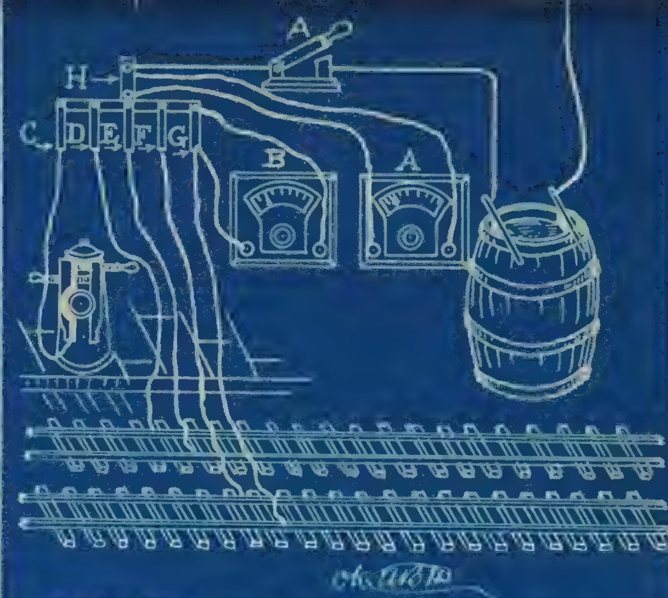
SEE DIAGRAM № 131

INSTRUMENTS REQUIRED ARE AS FOLLOWS: ONE AMMETER READING TO 20 AMPERES, ONE VOLT METER READING TO 20 VOLTS, ONE CALIBRATED RHEOSTAT OF 20 OHMS WITH CAPACITY OF 20 AMPERES, ONE WATER PLUG CONNECTION AND 40 FEET OF FLEXIBLE CABLE #6 B & S; 40 FEET OF #10 B & S CABLE; AND TRACK CLAMPS LIKE SHOWN IN SKETCH # 131.

THE CONNECTIONS TO BE MADE ARE TO CONNECT ALL RAILS TOGETHER TO A CABLE WHICH CONNECTS IN SERIES THE CALIBRATED RHEOSTAT AND AMMETER, AND THEN CONNECTED TO ONE SIDE OF THE PLUG CLAMP B. THE OTHER CONTACT OF THE PLUG CLAMP IS CONNECTED TO THE RAIL THROUGH THE VOLT METER. THE READINGS TO BE TAKEN ARE AS FOLLOWS: FIRST READ THE VOLTMETER WITH AMMETER CIRCUIT OPEN THEN CLOSE AMMETER CIRCUIT WITH NO RESISTANCE IN RHEOSTAT AND READ VOLTS AND AMPERES. THEN INSERT ENOUGH RESISTANCE IN RHEOSTAT TO MAKE THE VOLTMETER READ JUST ONE HALF THE AVERAGE VOLTS OF THE PREVIOUS VOLT METER READINGS, THEN THE RESISTANCE INSERTED IN THE RHEOSTAT IS EQUAL TO THE RESISTANCE BETWEEN THE TRACK AND THE WATER PIPE SYSTEM. WHILE THIS CONCLUSION IS



TEST FOR MEASURING RESISTANCE BETWEEN PIPE AND RAILS Nº 131



TEST FOR MEASURING RELATIVE VALUES OF RETURNS Nº 136

NOT ABSOLUTELY TRUE IT GIVES RESULTS NEARER THE TRUTH THAN THE DAILY VARIATION OF RESISTANCE BETWEEN WATER PIPES AND THE RAIL RETURN CIRCUIT.

THE PRACTICAL PURPOSES OF THESE TESTS ARE: TO LOCATE METALLIC CONNECTIONS BETWEEN RAILS AND SUBTERRANEAN METALLIC STRUCTURES; TO LOCATE NEUTRAL TERRITORY WHERE THERE IS NO TENDENCY FOR THE CURRENT TO LEAVE THE RAILS OR PIPE SYSTEM; AND IT WILL LOCALIZE THE DISTRICTS WHERE THE CURRENT LEAVES THE WATER PIPE SYSTEM AND ENTERS THE RAILS, AND THIS IS THE DISTRICT WHERE DESTRUCTIVE ELECTROLYSIS MAY OCCUR.

THE ABOVE TESTS WILL NOT GIVE ALL THE NECESSARY INFORMATION REGARDING ELECTROLYTIC CONDITIONS IN ORDER TO INDICATE THE CORRECT REMEDY.

THE NEXT TEST IS ALSO NECESSARY.

Apparatus .... No. of Sheet ....

Instruments .... Date ....

Given Data .... Name ....

Apparatus ....

Instruments ....

Given Data ....

No. of Sheet ....

Date ....

Name ....

Name of Ex. | No. of Ex.

Apparatus | No. of Sheet

Instruments | Date

Given Data | Name

EUGENE DIETZGEN CO., CHICAGO.